UNIVERSITY

TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

INJURIES IN RUGBY LEAGUE: INCIDENCE, INFLUENCES, TACKLES AND RETURN TO PLAY DECISIONS

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A thesis submitted to the Auckland University of Technology in fulfilment of the degree of Doctor of Philosophy

April 2010

School of Sport and Recreation

Primary Supervisor - Professor Patria Hume

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Chapters 2 to 14 of this thesis represent separate papers that have either been published or have been submitted to peer-reviewed journals for consideration for publication. My contribution and the contributed by the various co-authors to each of these papers are outlined at the beginning of each chapter. All co-authors have approved the inclusion of the joint work in this doctoral thesis.

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Douglas Alistair King

01 April 2010

CANDIDATE CONTRIBUTIONS TO CO-AUTHORED PAPERS

Chapter publication reference		Author %
Chapter 2.	King, DA., Hume, P., Milburn, P. & Guttenbeil, D. Match and training injuries in rugby league: A review of published studies. *Sports Medicine.* 2009. **40**(2):163-178.	DK: 85% PH: 10% PM: 3% DG: 2%
Chapter 3.	King, DA., Hume, P., Milburn, P. & Guttenbeil, D. A review of physiological and anthropometrical characteristics of rugby league players. *South African Journal for Research in Sport, Research and Recreation.* 2009. **31**(2):49- 67.	DK: 85% PH: 10% PM: 3% DG: 2%
Chapter 4.	King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: A review of eight years of Accident Compensation Corporation injury entitlement claims and costs. *British Journal of Sports Medicine.* 2009. **43**(8): 595-602.	DK: 85% PH: 10% PM: 2% SG: 3%
Chapter 5.	King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: Variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation. *New Zealand Journal of Sports Medicine.* 2009. **36**(2): 48-55	DK: 85% PH: 10% PM: 2% SG: 3%
Chapter 6.	King, DA., Hume, P., Milburn, P & Gianotti, S. Women's rugby league injury claims and costs in New Zealand. *British Journal of Sports Medicine.* 2009. doi:10.1136/bjsm.2009.064683	DK: 85% PH: 10% PM: 2% SG: 3%
Chapter 7.	King, DA., Hume, P., Gianotti, S., & Clark, T. A retrospective review over 1999 to 2007 of head, shoulder and knee soft tissue and fracture-dislocation injuries in rugby league in New Zealand. Submitted to *International Journal of Sports Medicine.*	DK: 85% PH: 10% SG: 3% TC: 2%
Chapter 8.	King, DA., Hume, P. & Clark, T. Back and spine injuries in amateur rugby league: A review of ACC injury entitlement claims and costs. Submitted to *Journal of Science and Medicine in Sports.*	DK: 85% PH: 10% SG: 3% TC: 2%

Chapter 9. King, DA., Hume, P. & Clark, T. Tackles in professional rugby league: Player positions, rates, height and field location. Submitted to *International Journal of Performance Analysis in Sport.*	DK: 85% PH: 12% TC: 3%
Chapter 10. King, DA., Hume, P. & Clark, T. Nature of tackles that result in injury in professional rugby league. Submitted to *Research in Sports Medicine.*	DK: 85% PH: 12% TC: 3%
Chapter 11. King, DA., Hume, P. & Clark, T. Nature of tackles that result in injury by positional group in professional rugby league. Submitted *to Journal of Sports Medicine and Physical Fitness.*	DK: 85% PH: 12% TC: 3%
Chapter 12. King, DA., Hume, P. & Clark, T. Player perspective on recovery from injury due to rugby league participation. Submitted to *New Zealand Journal of Sports Medicine.*	DK: 85% PH: 12% TC: 3%
Chapter 13. King, DA., Hume, P. & Clark, T. First aid, injury prevention and concussion knowledge of team management, administrators and official in new Zealand. Submitted to *New Zealand Journal of Sports Medicine.*	DK: 85% PH: 12% TC: 3%

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There are many people who have been involved in my progress towards this project and have spurred my interest into research into the game I love and live. These are just but a few.

To Dr. Chris Hanna who first stirred the interest in research and has remained supportive from the end of an email. To Daniel Anderson who supported and encouraged me to further myself within the game academically. To Dr. Tim Gabbett who sat at the end of an email and guided me towards my first ever published study in rugby league and stirred the knowledge fire in me. To Dr Clive Dreyer who patiently guided me in my endeavours to further myself. To Dr. Peter Milburn, Dain Guttenbeil, Tony Iro, Rohan Smith and Lee Clark for their assistance in the research.

To my awesome supervisor Professor Patria Hume who is a leading light and was always there with support, knowledge and care towards my endeavours to achieve this research. I will always be truly indebted to you for your time and energy. For this I am grateful and forever thankful that you believed in me and my love of the game. To Trevor Clark, a true friend, colleague, mentor, support person, team coach and many other great aspects in my life. For the time and patience you have shown me towards this and other research in rugby league, I am truly grateful and forever indebted. I trust your PhD endeavours will be as enjoyable.

To my loving wife, Helen-Dawn and my ever patient children Zara, Elena and Nathaniel who for years have only ever seen the back of me as I spent hours on the computer working towards this. Forever I am in debt to the time, support, patience and tolerance they gave me.

And lastly this thesis is dedicated to Ted Johnson. Sadly Ted, loving husband of Mary, poppa to Geneva and Thomas and a friend to many league people passed away while I was doing the PhD. My lasting memory of Ted will always be the both of us standing on the sideline watching league and enjoying the short time we had together. Ted believed in me, supported me in my endeavours to achieve lots in the game and always had a positive view on all situations. Ted lost his battle with cancer aged 75 in 2009. The game has lost a true character, avid supporter and life time league loyalist. Many thanks Ted for the time, opportunities, support and love. Resting in peace and pain free now, Ted will always be with me in my writings and endeavours in rugby league.

ETHICS

Ethical approval for this research was granted by the Auckland University of Technology Ethics Committee (AUTEC) for:

1. AUTEC #0830 approved on 27th March 2008 for: The incidence, site and type of injuries that occur to different ethnic groups as a result of participation in rugby league activities.
2. AUTEC #0876 approved on 23rd May 2008 for: To identify whether changes in anthropometric and physiological characteristics over a playing season correlate to the incidence, site and type of injuries recorded over the same period..
3. AUTEC #0830 approved on 4th April 2008 for: Injuries in rugby league: incidence, limb dominance effects, and return to play decisions. .

Ethical approval was granted by the Health and Disability Ethics Committees (Central Regional Ethics Committee) for:

1. Central Regional Ethics Committee CEN/09/56/EXP approved on 26th February 2010 for: Injury knowledge of rugby league coaches: A district experience

ABSTRACT

Rugby league is an international collision sport. Players complete physically demanding activities such as running, tackling and passing which often result in musculoskeletal injuries. Injury rates increase as playing level increases. From 1999 to 2007 there were 42,754 rugby league claims costing Accident Compensation Corporation $48,704,704. Moderate to severe injury claims (MSC) represented 14% of these claims but 88% of costs. New Zealand Maori recorded significantly more injury claims and total injury entitlement costs than all other ethnic groups. Soft tissue MSC injuries were common (47%) for females. Concussions accounted for 70% of total rugby league injuries to the head while the knee represented 23% of total injury claims and 20% of injury costs. Neck and spine injuries accounted for 6% of total MSC injury claims but 16% of total MSC costs.

In video analysis of 80 games at international, national and youth competition levels, 50% of tackles involved tacklers from behind the visual fields of the ball carrier, either two or three tacklers, and contact with the mid-torso or hip-thigh region. From the prospective injury analysis of one professional team over two consecutive years, tackle-related injuries occurred more to the ball carrier when tackled at shoulder or mid-torso height, in their blind vision, with two or more tacklers, and in the fourth quarter of matches. Tackle-related injury type and site varied by positional group. Hit-up forwards and outside backs recorded more tackle-related injuries as the ball carrier than the tackler.

In the prospective study of 63 amateur rugby league players, 80% of players injured as a result of match or training activities saw a health professional as part of their rehabilitation. Team coaches asked players to return to rugby league activities in 28% of cases for training participation and 29% of cases for match participation. In the cross sectional study assessing 95 rugby league support personnel's first aid, injury prevention and concussion knowledge, only 2% achieved an 80% pass mark, 39% incorrectly stated loss of consciousness was required for concussion and only 24% of coaches had a rugby league coaching qualification.

This PhD research has contributed knowledge regarding costs and characteristics of injuries to amateur rugby league participants analysed by ethnicity, gender, injury site and injury type. Changes in anthropometric characteristics and speed in regards to incidence of injury, characteristics of tackles in match situations and common tackling positions and positional groups where injuries occur, player perspectives on why they return from injury to participation in rugby league, and the lack of first aid knowledge for rugby league personnel, have all been described.

PERSONAL VIEW

Growing up as a child on the West Coast meant being immersed in the stronghold of rugby league of New Zealand. Naturally the game became part of my life from an early age. Rugby league is a contact sport where injuries occur but in New Zealand, it is a minority sport and the resources and support for the game is limited to say the least. Having suffered an injury and having no-one available to assist in my rehab meant I turned my nursing knowledge towards learning more about how these injuries occur and how to treat them. Consequently over a passage of time I have attained knowledge and academic qualifications in sports medicine that I have been able to utilise for the care of rugby league players.

In attaining these qualifications my interest grew and I started to venture into researching rugby league injuries in New Zealand. With the support of Tim Gabbett I published my first article and my journey towards the PhD had begun. Many questions were developed over the lead up towards applying for a position as a PhD student and, having achieved my Masters, these became more focused as to why these injuries occurred, what was the economic costs of these injuries and how can we prevent them.

Having commenced the literature review for match and training injuries in rugby league, and anthropometric characteristics of rugby league players, it became more obvious that in New Zealand there was a paucity of information relating to rugby league and that there were areas that were not reported internationally. This lead to a more formal structure of the PhD thesis looking to address the question of what is the epidemiology of rugby league injuries in New Zealand and what are the risk factors for rugby league injuries.

Epidemiology of rugby league injuries in New Zealand

The national body for rugby league in New Zealand, the NZRL, has no formalised collection of player numbers, injuries that occur and the ethnicity of players participating in the game. To try to identify the rate of injuries in New Zealand would require the use of inconsistent data and incomplete player registrations. As a result trying to establish the injury incidence rate was not undertaken.

Although Gabbett and Meir had previously reported on the costs of rugby league injuries, this was undertaken as a survey. There have been several studies published identifying that there are limitations to the accuracy of the results of surveys. I can remember my last rugby league game down to who scored the last try, but for the life of me I cannot remember the last injury I had. The reporting of the costs of rugby league injuries appeared to be an elusive exercise with no real means of truly identifying the costs related to any injury that occurs from rugby league participation.

Through the assistance of Simon Gianotti, access was obtained to the Accident Compensation Corporation's database. Data pertaining to the costs, site, type, incidence, gender and ethnicity of people making rugby league injury entitlement claims was downloaded and analysed. This analysis was utilised to formulate Chapters 4 to 8.

A review of eight years of Accident Compensation Corporation injury entitlement claims and costs

In reviewing 8 years of rugby league injury claims in Chapter 4 a snap shot was produced of nearly 6000 injury entitlement claims for those injuries classified as moderate to serious. Surprisingly this was only 14% of the total injury claims but accounted for 89% of the total costs. This study provided for the first time a longitudinal view of the costs of injuries in rugby league identifying that the knee was the most common injury site and soft tissue injuries were the most common injury type requiring medical treatment, which is consistent with other international studies on rugby league epidemiology.

Variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation

So the next question I had from this data analysis was whether there was any difference in the injury rate, site and type between the different ethnicities that play rugby league. Is one ethnic group more at risk of injury types or sites than other groups? To date no other published study in rugby league has undertaken to report on ethnic variations in rugby league injuries. This study was the first study I am aware of to incorporate ethnicity into injury epidemiology in sports injuries. Although New Zealand Maori account for just 13% of the population, they recorded nearly half of the injury entitlement claims. This may be reflective of the status of rugby league in New Zealand as a blue collar sport where more Maori participate than other ethnic population groups. The findings in this study were not expected in regards to the mean costs per concussion claim. New Zealand Maoris recorded a higher mean cost per claim than any other ethnic group and than the total mean cost per claim overall. As well there was a decrease in the rate of injury claims over the study period for New Zealand Maori and Europeans but there was an increase for Pacific

Islanders and Asians. Is this reflective of the changing face of rugby league or the way in which people utilise medical services for the care of their injuries? Further research is warranted in this area.

Women's rugby league injury claims and costs in New Zealand

Only two other published articles are specifically related to women's rugby league. Gabbett reported on the anthropometric and physiological characteristics of the Australian women's rugby league team while I reported on a women's rugby league tournament over a 4 day period. To undertake a study on women's rugby league in New Zealand was seen as important as we are the home of the current women's world cup champions, the 'Kiwi Ferns' and there is a definite paucity of published studies in women's rugby league. With the available data I was able to separate female from male injury claims and, although only accounting for 6% of injury entitlement claims there was a definite pattern appearing with a higher proportion of lower limb injuries and claims to the lower limbs than male rugby league participants. Similar to the previous studies concussions recorded the highest mean cost per injury entitlement claim as did the head but the knee was the most commonly injured injury site and New Zealand Maori were disproportionately represented. The results of this study suggest that although there are injury prevention programs for rugby league, injury prevention programs should also be developed specifically for women participants in rugby league. More studies are warranted in this population group to enable a broader knowledge of women rugby league participants.

Head, knee and shoulder injuries from rugby league in New Zealand: Changes over eight years

Following journal reviewers' feedback the paper from this chapter has now been. In addition the data pertaining to concussions and the related discussion sections have also been removed. Most published studies provide a snap shot of the injuries reporting the player position, injury type and site but what injury type actually occurs to the injury site reported? In addition on longitudinal studies is there a change to the injury type and site and are we actually aware of what we can expect in the future?

By using the ACC data to identify the top three most common injury regions; the knee, shoulder and head and neck were examined. By using this approach we can see what is occurring in the game and look forwards to what we need to focus on. The use of this study can be seen to be able to show changes in the match and training dynamics which may be reflective of changes seen in rugby league at the professional level of participation.

Neck, back and spine injuries in amateur rugby league: A review of nine years of Accident Compensation Corporation injury entitlement claims and costs

There is nothing more anxiety producing as a sideline medic to see than a player tackled around the neck or driven into the ground and unable to get up, or worse still not able to move their limbs. Having attended a few of these injuries during my role as a trainer/medic I have observed that not many team trainers are trained, let alone prepared to manage these injuries as they are not a common injury. Although it is difficult to stop these injuries occurring, knowledge of the number, costs and consequences of these injuries can assist in making team management aware of the consequences that these injuries can result in. Injuries to the neck and spine can have catastrophic life changing consequences and no study to date has explored these specifically for amateur rugby league participants.

Risk factors for rugby league injuries

Initially all requests for data for analysis was met with "commercially sensitive" replies from the professional level of rugby league participation in both the northern and southern hemispheres. Despite this, one professional club did agree, through personal contact, to the release of information pertaining to the injuries of players over a two year period and the anthropometric and physiological characteristics of rugby league players. This data was provided but on the agreement that this team was (a) not identified and (b) the raw data was not released to another other rugby league entity. The data provided was limited to a two year period for the injuries recorded and with the available recorded pre-season tests completed. This was a major limitation to the studies that resulted from this data.

Video analysis of tackles in professional rugby league by player position, tackle height and tackle location

The tackle has been reported as the most common cause of injury in all studies reporting injuries in rugby league. Although Gabbett has been producing articles recently in areas such as characteristics of good and bad tackles, fatigue effects and the anthropometric influences in tackle technique no study has reported on the tackle under match type conditions. The question for me here was how can we report on influences and characteristics of the tackle and its involvement in injury if we don't actually know what typically occurs with the tackle, who is tackled most commonly, by who and where on the field does this occur? Being a qualified rugby league coach and elite level trainer I have had years of continuation training in tackle technique and entered into this study with this knowledge at the forefront of what I would find. Surprisingly what I perceived was going to be the direction, type and height of the tackle in the modern game of rugby league was not what was identified through the study, nor was it what is taught in coaching and trainer educational courses. Although this study does not report injury types or sites, it does identify for the first time what occurs in the tackle in rugby league, where the tackle most commonly occurs on the field of play and what the most common height, direction and side that the tackle occurs on the ball carrier in match conditions. The findings of this study were beneficial for the other studies I was about to undertake and has been used in coaching courses I have presented at.

Nature of tackles that result in injury in professional rugby league

Studies reporting injuries in professional rugby league have dominated the published rugby league literature. John Gibbs original study reported on his findings as the medical officer for the South Sydney Rabbitoh's and this has been the basis for many other published studies. As previously identified injuries from the tackle are reported to be the most common in rugby league. Yet despite this finding no study to date has reported on what occurs during the tackle when an injury occurs. This study reported on just the tackle that resulted in an injury being reported for both the ball carrier and the tackler. By reviewing two years of matches from one professional team and specifically focusing on those players who recorded an injury in the match an analysis was undertaken to record the height, direction, player position, role as either ball carrier or tackler, number of tacklers involved in the tackle, field location and match time that the injuries occurred.

The effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches

Many studies have reported player injuries by the roles in which they play. Any follower of rugby league will identify that certain player positions have specific roles and often are involved in more tackles, hit-ups and tries than other player positions. By grouping the tackle related injuries into player groups (hit-up forwards, adjustables and outside backs) it was shown that different player groups recorded different injuries when involved in the tackle as both the tackler and the ball carrier. It also highlighted for me how the game differs for the different player groups, especially in regards to injuries and when they occur in the match. Although this was conducted at the professional level of participation, research of other levels of participation would assist in broadening the information reported in this chapter to see whether match injuries are similar for these player positional groups.

Player perspective on return to play following a match or training injury in amateur rugby league

Amateur rugby league players represent the majority of rugby league participant's world wide. As they are amateur they source their income from activities outside of rugby league and any injury on this group of players has wide reaching effects such as loss of income, social isolation and decreased physical activity participation. Yet injured amateur rugby league players' return to the game and will often do this despite the injury not being fully rehabilitated or having had any form of health professional rehabilitation. As an amateur player I was injured which placed my employment at risk as I was not able to walk or drive as my job required. Despite approaching health care professionals, I was left to get myself better. When I felt I was ok I went back to play only to be re-injured but this time it took longer for me to get back onto the field to play again. I also have many memories of injured players disappearing from the match and training environment when injured only to return a few weeks later and want to return to playing. Unfortunately many of these players were re-injured and missed more match time. So why do players with injuries return before medically cleared and do they see any rehabilitation specialists? By conducting this study I hoped to be able to gain a better understanding of the influences and player perspective of returning to match and training participation following an injury. The study provided me as a health professional an insight to why players return to sport, what they think of the advice provided for return to sport and a better understanding of what makes the players put their employment and bodies at risk of further injury.

First aid, injury prevention and concussion knowledge of rugby league team management, administrators and officials in New Zealand

Management of injuries, awareness of potential risks, complications from injuries and the identification and management concussions is an important part of my role as a team medic. But I am only one person in a competition covering more than 100 teams at various levels. I am often amazed at the team management's responses to injuries occurring and how they put the match at a higher priority than the player, putting players back on the field despite them having an injury that can become worse. Having had a player die in my arms from a team I was not associated with highlighted to me the lengths some team management will go to in winning a game. Having had exposure at every level of rugby league and at several national, international and regional levels of rugby union I have seen concussions hidden, injuries taped to keep players going and injured players left on the field to harden up. I have been involved at a national level trying to raise the first aid and concussion knowledge of team management over several years but to date little progress has been made.

In conducting this study I wanted to identify what level of first aid and concussion knowledge there was amongst team management in rugby league. Team management were provided with a questionnaire on first aid knowledge and concussion awareness. Initially this was met with resistance as this has not been a focus of the national body in regards to minimum requirements. Several concerns were raised when conducting this research and this was due to the score of the first aid knowledge and the score of recognizing concussion symptoms. By undertaking this research it was identified that coaches were unable to meet the minimum first aid pass mark as identified by first aid agencies in New Zealand and that there was a lower understanding of sports-related concussion than previously reported. This information was initially not going to be included in the thesis as it portrays a negative picture of rugby league, but following conversations with several people it was decided to include this into the thesis to highlight a concern that people may not be able to recognise the injuries nor the severity and may not undertake the best treatment recommendations possible for the players. A possible result of this finding can be seen in the findings reported in chapters 4 to 8.

Summary

Although the thesis studies have been conducted to the best of my ability there were several limitations identified and reported. These limitations can, in my opinion, be attributed to the limited support available for a researcher looking at rugby league injuries outside of the professional rugby league umbrella. In addition, the availability and consistency of data available to utilise combined with the different focus of the rugby league community in regards to player injury and injury prevention may also have contributed to the limitations encountered when conducting this research.

In summary this thesis has addressed the question of what is the epidemiology of rugby league injuries in New Zealand and what are the risk factors for rugby league injuries by describing the prevalence, nature, costs, and factors such as gender, tackle technique, and first aid management. In preparing for this oral examination it has helped me to more clearly outline the rationale, limitations and links between the chapters. As well, the feedback by reviewers on those chapters not yet published has helped to further enhance the quality of this thesis.

This is not the end of my interest in researching aspects of rugby league and has helped me to focus on other questions that have developed as a result of this research.

RESEARCH PUBLICATIONS RESULTING FROM THIS DOCTORAL THESIS

Section 1: Reviews of literature for rugby league injuries.

Chapter 2: Match and training injuries in rugby league: A review of published studies.

King, DA., Hume, P., Milburn, P. & Guttenbeil, D. Match and training injuries in rugby league: A review of published studies. *Sports Medicine* 2009. **40**(2): 163-178

(Author contribution percentages: DK: 85%, PH: 10%, PM: 2%, DG: 3%)

Chapter 3: A review of physiological and anthropometrical characteristics of rugby league players.

King, DA., Hume, P., Milburn, P. & Guttenbeil, D. A review of physiological and anthropometrical characteristics of rugby league players. *South African Journal for Research in Sport, Research and Recreation* 2009. **31**(2): 49-67.

(Author contribution percentages: DK: 85%, PH: 10%, PM: 2%, DG: 3%)

Chapters 2 and 3 appendix (Appendix 1): Rugby League: Beginnings, injury definitions, injury incidence and anthropometric aspects. A technical report for New Zealand Rugby League.

King, DA., Hume, P. & Milburn, P. Rugby League: Beginnings, injury definitions, injury incidence and anthropometric aspects. A technical report for New Zealand Rugby League. 11th June 2008. Reviewed by Dain Guttenbeil, New Zealand Rugby League

(Author contribution percentages: DK: 85%, PH: 13%, PM: 2%)

Section 2: Epidemiology of rugby league injuries in New Zealand.

Chapter 4: Rugby league injuries in New Zealand: A review of eight years of Accident Compensation Corporation injury entitlement claims and costs.

King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: A review of eight years of Accident Compensation Corporation injury entitlement claims and costs. *British Journal of Sports Medicine* 2009. **43**(8): 595-602.

(Author contribution percentages: DK: 85%, PH: 10%, PM: 2%, SG: 3%)

Chapter 5: Rugby league injuries in New Zealand: Variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation.

King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: Variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation. *New Zealand Journal of Sports Medicine* 2009. **36**(2): 48-55

(Author contribution percentages: DK: 85%, PH: 10%, PM: 2%, SG: 3%)

Chapter 6: Women's rugby league injury claims and costs in New Zealand.

King, DA., Hume, P., Milburn, P & Gianotti, S. Women's rugby league injury claims and costs in New Zealand. *British Journal of Sports Medicine* 2009. doi:10.1136/bjsm.2009.064683

(Author contribution percentages: DK: 85%, PH: 10%, PM: 2%, SG: 3%)

Chapter 7: A retrospective review over 1999 to 2007 of head, shoulder and knee soft tissue and fracture-dislocation injuries in rugby league in New Zealand.

King, DA., Hume, P., Gianotti, S., & Clark, T. A retrospective review over 1999 to 2007 of head, shoulder and knee soft tissue and fracture-dislocation injuries in rugby league in New Zealand. Submitted to *International Journal of sports Medicine.*

(Author contribution percentages: DK: 85%, PH: 10%, SG: 3%, TC 2%)

Chapter 8: Back and spine injuries in amateur rugby league: A review of nine years of Accident Compensation Corporation injury entitlement claims and costs.

King, DA., Hume, P., Gianotti, S., & Clark, T. Back and spine injuries in amateur rugby league: A review of nine years of Accident Compensation Corporation injury entitlement claims and costs. Submitted to *Journal of Science and Medicine in Sport*.

(Author contribution percentages: DK: 85%, PH: 12%, TC: 3%)

Section 3: Risk factors for rugby league injuries.

Chapter 9: Video analysis of tackles in professional rugby league by player position, tackle height and tackle location.

King, DA., Hume, P., & Clark, T. Video analysis of tackles in professional rugby league by player position, tackle height and tackle location. Submitted to *International Journal of Performance Analysis in Sport*.

(Author contribution percentages: DK: 85%, PH: 12%, TC 3%)

Chapter 10: Nature of tackles that result in injury in professional rugby league.

King, DA., Hume, P & Clark, T. Nature of tackles that result in injury in professional rugby league. Submitted to *Research in Sports Medicine*.

(Author contribution percentages: DK: 85%, PH: 12%, TC: 3%)

Chapter 11: The effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches.

King, DA., Hume, P., & Clark, T. The effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches. Submitted *to Journal of Sports Medicine and Physical Fitness.*

(Author contribution percentages: DK: 85%, PH: 12%, TC 3%)

Chapter 12: Player perspective on return to play following a match or training injury in amateur rugby league.

King, DA., Hume, P., & Clark, T. Player perspective on return to play following a match or training injury in amateur rugby league. Submitted to *New Zealand Journal of Sports Medicine*.

(Author contribution percentages: DK: 85%, PH: 12%, TC: 3%)

Chapter 13: First aid, injury prevention and concussion knowledge of rugby league team management, administrators and officials in New Zealand

King, DA., Hume, P., & Clark, T. First aid, injury prevention and concussion knowledge of rugby league team management, administrators and officials in New Zealand. Submitted to *New Zealand Journal of Sports Medicine*.

(Author contribution percentages: DK: 85%, PH: 12%, TC: 3%)

Other publications since starting the Doctor of Philosophy

King, DA. & Gissane, C. Injuries in amateur rugby league matches in New Zealand: A comparison between a division 1 and a division 2 premier grade team. *Clinical Journal of Sports Medicine* 2009. **19**(4): 277-281.

King, DA. & Gabbett, T. Training injuries in New Zealand amateur rugby league players. *Journal of Science and Medicine in Sports* 2009. **11**(6): 562-565.

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King, DA. & Shaw, K. Minor Injury Clinic's in an Emergency Depart: The Hutt Valley experience. *Emergency Nurse New Zealand.* 2008. **Winter:** 6-12.

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King, DA. Minor injury clinic in the Emergency Department: a year in review. *Emergency Nurse New Zaland.* 2009. **Winter**: 9-16.

King, DA, Clark, T & Kellmann, M. Changes in stress and recovery as a result of participating in a premier rugby league representative competition. *International Journal of Sport Science and Coaching* 2010. **5**(2): 223-237

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King, DA. Sports Related Concussion in the Emergency Department. *College of Emergency Nurses Conference.* August 2008.

King, DA. Banned Substances in the Emergency Department. *Oceania Anti-Doping Educators Conference.* November 2008.

King, DA. Nurse led clinics in the Emergency Department: Small steps in a big path. *Clinical Nurse Manager and Duty Nurse Manager Section Annual Conference.* November 2009.

King, DA. Shaw, K., Flaws, M. & Kippax, C. Pathways to nurse led clinics in the Emergency Department. *Nurses Grand Round.* November 2009.

King, DA. & Press, M. Small steps on a long pathway: From Nurse Track to Clinical Nurse Specialist. Autonomous nurse practice in the ED setting. *Nurses Grand Round*. July 2010.

King, DA. & Press, M. Small steps on a long pathway: Development of minor injury care pathway in the Emergency Department. *2nd Improving the Delivery of Emergency Care Conference*. August 2010. Cararra, Queensland, Australia.

CHAPTER 1: INTRODUCTION AND RATIONALISATION (PREFACE)

Background

The most commonly cited framework in sports injury prevention is the sequence of injury prevention framework.[244] This framework (see Figure 1) outlined a four stage approach towards sports injury prevention representing a translation of the standard health prevention model to the sports injury context.[63] When this framework was first published, the aspects of the first (extent and severity of injury) and second (aetiology) stages of the four stage framework were the primary focus in the development towards injury prevention programs. Despite the development of sequence of injury prevention framework and its world-wide uptake, rugby league research has been limited to primarily the extent and severity of injuries at professional/elite and semi-professional/sub-elite levels of participation. There are a few studies reporting the extent and severity of injuries at amateur and junior levels of participation but there is a paucity of studies directly focusing on the aetiology and mechanisms of injuries in rugby league.

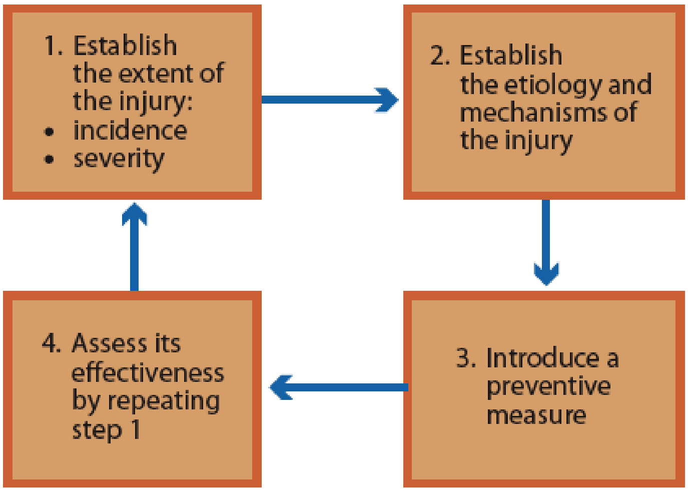

Figure 1: The four steps in the sequence of prevention of sports injuries[244]

Rugby league is an international collision sport played by junior, amateur, semi-professional and professional players.[87, 159] To compete participants are required to be involved in physically demanding activities such as running, tackling, passing and sprinting and musculoskeletal injuries are common.[87, 159] The majority of injuries occur in the match environment with rates typically increasing as the playing level increases.[66, 75, 141] The tackle has been reported to be the most common cause of injuries with between 46–90% of all injuries that occurred in matches being tackle related.[66, 75, 140] Although there are several published studies on the rate of injury at all levels of participation there is a paucity of information relating to participation in rugby league activities in several areas: (1) Amateur participation in New Zealand; (2) The nature of tackles and injuries as a result of the tackle; (3) Decisions and influences of players returning to participation from injury; and (4) First aid knowledge of team management and officials.

This lead to the formulation of section themes contained in this thesis: Section 1 contains reviews of the published literature for rugby league; Section 2 describes the epidemiology of rugby league injuries in New Zealand; Section 3 examines risk factors for rugby league injuries.

Structure

The thesis is structured as a series of related chapters (see Figure 2) that culminate in an overall discussion (Chapter 15). Most of these chapters have been submitted for publication in journals which has allowed the author to gain international peer reviewed feedback on the content. As a result of this international feedback the relevant chapters have been improved. A technical report has also been provided to New Zealand Rugby League providing them with feedback useful for their injury prevention programmes (see Appendix 2), and to gain feedback to aid in development of projects for later chapters.

The first thematic section of the thesis (Chapters 2-3) is focused on **Reviews of literature for rugby league**. Chapter 2 (published in *Sports Medicine*, 2010) comprises a review of the literature on match and training injuries by updating the descriptive data on rugby league epidemiology and adds information for semi-professional, amateur and junior levels of participation in both match and training environments using studies identified through searches of databases. This chapter also discusses the issues surrounding the definitions of injury exposure, injury rate, injury severity, and classification of injury site and type for rugby league injuries. Chapter 3 (published in *South African Journal for Research in Sport, Research and Recreation*, 2009) was undertaken to determine the anthropometric and physiologic characteristics of rugby league players based on a review of literature using studies identified through searches of databases. Publications resulting from Chapters 2 and 3 were:

King, DA., Hume, PA, Milburn, PD., Guttenbeil, D. Match and training injuries in rugby league: A review of published studies. Sports Medicine. 2010; **40**(2): 163-178

King, DA., Hume, PA., Milburn, PD., Guttenbeil, D. A review of physiological and anthropometrical characteristics of rugby league players. South African Journal for Research in Sport, Research and Recreation. 2009. **31**(2): 49-67.

King, DA., Hume, P. & Milburn, P. Rugby League: Beginnings, injury definitions, injury incidence and anthropometric aspects. A technical report for New Zealand Rugby League. 11th June 2008. Reviewed by Dain Guttenbeil, New Zealand Rugby League. 63 pages.

The second thematic section of the thesis (Chapters 4-8) examined **Epidemiology of rugby league injuries in New Zealand**. Chapter 4 (published in *British Journal of Sports Medicine*, 2009) reports on the total and mean costs of Accident Compensation Corporation (ACC) moderate to serious injury entitlement claims (MSC) for rugby league over an eight year period. Chapter 5 (published in *New Zealand Journal of Sports Medicine*, 2010) reports further analyses of the ACC MSC's by reviewing the injury entitlements claims and costs by ethnicity, gender, age, district, body site and type and occupational groups. Chapter 6 (*British Journal of Sports Medicine*, 2010 in print) reports on women's rugby league ACC MSC costs and claims while Chapter 7 (submitted to *International Journal of Sports Medicine*) reports the most commonly reported injury types and sites, the head, knee and shoulder in New Zealand. Chapter 8 (submitted to *Journal of Science and Medicine in Sport*) reports analyses of the ACC MSC claims for back and spine injuries reporting on costs, types and changes over a nine year period. Publications resulting from Chapters 4-8 were:

King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: A review of eight years of Accident Compensation Corporation injury entitlement claims and costs. *British Journal of Sports Medicine.* 2009. **43**(8): 595-602.

King, DA., Hume, P., Milburn, P & Gianotti, S. Rugby league injuries in New Zealand: Variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation. *New Zealand Journal of Sports Medicine.* 2009. **36**(2): 48-55.

King, DA., Hume, P., Milburn, P & Gianotti, S. Women's rugby league injury claims and costs in New Zealand. *British Journal of Sports Medicine.* 2010. doi:10.1136/bjsm.2009.064683.

Manuscripts submitted for publications resulting from Chapters 4 to 8 were:

King, DA., Hume, P., Gianotti, S., & Clark, T. Injuries from rugby league in New Zealand. Submitted to *International Journal of Sports Medicine.*

King, DA., Hume, P., Gianotti, S., & Clark, T. Neck, back and spine injuries in amateur rugby league: A review of nine years of Accident Compensation Corporation injury entitlement claims and costs. Submitted to *Journal of Science and Medicine in Sport.*

The third thematic section of the thesis (Chapters 9-13) examined **Risk factors for rugby league injuries**. Chapter 9 (submitted to *International Journal of Performance Analysis in Sport*) reports on the nature of tackles from 80 matches of professional rugby league participants over a competition season for International, National Rugby league and National Youth Competitions. Chapter 10 (submitted to *Research in Sports Medicine*) reports on the nature of tackles that result in injuries for professional participants while chapter 11 (Submitted to *Journal of Sports Medicine and Physical Fitness*) reports on the nature of tackles that result in injuries by positional groups. Chapter 12 (submitted to *New Zealand Journal of Sports Medicine*) reports on amateur rugby league influences and decisions in returning to play from a missed match injury. Chapter 13 (submitted to *New Zealand Journal of Sports Medicine*) reports on the first aid, injury prevention and concussion knowledge of rugby league team management, administrators and officials. Manuscripts submitted for publications resulting from Chapters 9-14 were:

King, DA., Hume, P., & Clark, T. Video analysis of tackles in professional rugby league by player position, tackle height and tackle location. Submitted to *International Journal of Performance Analysis in Sport.*

King, DA., Hume, P., & Clark, T. Nature of tackles that result in injuries in professional rugby league. Submitted to *Research in Sports Medicine.*

King, DA., Hume, P., & Clark, T. The effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches. Submitted to *Journal of Sports Medicine and Physical Fitness.*

King, DA., Hume, P., & Clark, T. Player perspective on return to play following a match or training injury in amateur rugby league. Submitted to *New Zealand Journal of Sports Medicine.*

King, DA., Hume, P., & Clark, T. First aid, injury prevention and concussion knowledge of rugby league team management, administrators and officials in New Zealand. Submitted to *New Zealand Journal of Sports Medicine*.

Chapter 14 consists of a general discussion of findings from the presented research projects, comments on limitations to the research studies, provides areas for future research, and provides some concluding statements on the key findings from the thesis.

The appendices contain material for the chapters that were presented as technical reports to New Zealand Rugby league or as supplemental data. A sample subject consent form and information pack is provided in Appendices 2 and 3. Appendix 4 contain notifications from the Auckland

University of Technology Ethics Committee (AUTEC) and the Health and Disability Ethics Committees (Central Regional Ethics Committee) regarding ethical approval where required. Appendices 5 to 8 contain data for Chapters 9 to 11.

Figure 2. Overview of doctoral thesis chapter flow.

CHAPTER 2: MATCH AND TRAINING INJURIES IN RUGBY LEAGUE: A REVIEW OF PUBLISHED STUDIES

This chapter comprises the following paper accepted by *Sports Medicine:*

Reference

King, DA., Hume, P., Milburn, P. & Guttenbeil, D. Match and training injuries in rugby league: A review of published studies. *Sports Medicine.* 2009. **40**(2):163-178

Author contribution

King, D. 83%; Hume, P. 10%; Milburn, P. 5%; Guttenbeil, D. 2%.

Overview

Rugby league is an international collision sport played by junior, amateur, semi-professional and professional players. The game requires participants to be involved in physically demanding activities such as running, tackling, passing and sprinting and musculoskeletal injuries are common. A review of injuries in junior and senior rugby league players published in *Sports Medicine* in 2004 reported that injuries to the head and neck and muscular injuries were common in senior rugby league players while fractures and injuries to the knee were common in junior players. This current review updates the descriptive data on rugby league epidemiology and adds information for semi-professional, amateur and junior levels of participation in both match and training environments using studies identified through searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases. This review also discusses the issues surrounding the definitions of injury exposure, injury rate, injury severity, and classification of injury site and type for rugby league injuries. Studies on the incidence of injuries in rugby league have suffered from inconsistencies in the injury definitions utilised. Some studies on rugby league injuries have utilised a criterion of a missed match as an injury definition, total injury incidences or a combination of both time-loss and non-time-loss injuries, while other studies have incorporated a medical treatment injury definition. Efforts to establish a standard definition for rugby league injuries have been difficult as some researchers were not in favour of a definition that was all encompassing and enabled non-time-loss injuries to be recorded. A definition of rugby league injury has been suggested based on agreement by a group of international researchers. The majority of injuries occur in the match environment with rates typically increasing as the playing level increases. However, professional level injury rates were reportedly less than semi-professional participation. Only a few studies have reported training injuries in rugby league where injury rates were reported to be less than match injuries. Approximately 16 to 30% of all rugby league injuries have been reported as severe placing demands upon other team members and, if the player returns to playing too early, places them at an increased risk of further injuries. Early research in rugby league identified that ligament and joint injuries were the common injuries and occurred primarily to the knee. More recently studies have shown a change in anatomical sites being injured at all levels of participation. Although the lower limb was the frequent injury region reported previously, the shoulder has now been reported to be the most common injury site. Changes in injury site and type could be used to prompt further research and development of injury reduction programs to readdress the issue of injuries that occur as a result of participation in rugby league activities. Further research is warranted at all participation levels of rugby league in both the match and training environments to confirm the strongest risk factors for injury.

Introduction

Rugby league is a team contact sport participated internationally that consists of 13 players in each team. It is typically (but not always) played under a limited interchange rule where up to 12 interchanges of players are permitted in matches. Each team is permitted six tackles in possession of the ball with which they must advance into the opposition's territory and score a try.[75, 99, 103] The ball must only be passed backwards but can be carried or kicked into the opposition's territory.[87, 118] At the completion of six tackles the ball is immediately given to the opposition team to commence their set of six tackles.[87, 114] Most teams often kick the ball after the fifth tackle (ceding the possession to the opposition) to avoid being tackled a sixth time, in an attempt to gain further territorial advantage. The same players are therefore involved in both attack and defence.

As with all sport, there is a risk of sustaining an injury when participating in rugby league activities. The game is intermittent in nature requiring participants to compete in a challenging physical contest. Players' often undergo frequent bouts of high intensity activity (e.g., tackling, sprinting, running and passing) interspersed with short bouts of low intensity activity (e.g., jogging, walking and standing).[27, 44, 104, 180] As a result of the intermittent and contact nature of the game, the physiological demands of rugby league are complex. Players are required to have maximal aerobic power, speed, muscular strength, and power and agility appropriately developed to be able to compete in the match environment[27, 44, 104, 180] and as a result of the physical and intense nature of the game, musculoskeletal injuries are common.[77, 87, 104]

The rugby league team consists of two main groups of participants (forwards and backs) on the field and reserves available for interchange.[37, 84, 183] The demands on the participants vary according to the specific positions played[37, 84, 183] with forwards (prop n=2, hooker n=1, second row n=2 and lock n=1) more predominately involved in large numbers of physical collisions and tackles.[78] Backs (half-back n=1, stand-off/five-eighth n=1, centre n=2, wing n=2 and fullback n=1) spend more time in free running but are also involved in tackles and collisions.[37, 78, 104, 183]

Aim

The aim of this study was to review and update the descriptive data on rugby league injury epidemiology and add information for semi-professional, amateur and junior levels of participation in both match and training environments.

Methods

Searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases were performed to identify studies published in English prior to October 2008. The computer databases provided access to sports-oriented and biomedical journals, serial publications, books, theses, conference papers, and related research published since 1948. Terms utilized for the search of relevant research studies included rugby league and injury incidence. Qualifying studies were mainly uncontrolled trials and the outcome variables were injury incidence, injury site, injury type, match time, seasonal variations, and injury severity of rugby league players.

Findings

Thirty-five published studies, mainly conducted in Australia and New Zealand, have reported the injury incidence of rugby league participants in matches (i.e. tournaments and competitions) and/or training (see Table 1). Tournaments differ from matches in two main areas: (1) tournament matches can vary in periods between matches (i.e. several matches in one day through to one game a week) and (2) they can comprise of players of different participation levels either playing against each other or competing in the same team. Conversely, matches are typically undertaken on a regular schedule over a longer period of time for a specific participation level. Injury incidence has changed with changes to the rules of the game and with the resulting changes to the activity and intensity at which the game is played. Although there have been World Cup tournaments for both male and female participants, there have been no published studies on the injury incidence in these competitions, and several levels of competition do not have females included (see Table 1).

The majority of rugby league participants are amateur (i.e. they derive income from another source), therefore the majority of injuries that occur from rugby league participation are incurred by these participants, but the rate of injury differs for professional players. Although there have been many studies reporting both match and training injures in rugby league and conducted at various levels of participation, there are some participation levels - such as masters and school level - where no prospective injury epidemiological studies have been completed. There was also a paucity of studies on amateur and junior levels of participation. While there is an assumption that the results of epidemiological studies on professional participants translate to other cohorts of participants in other countries, these assumptions have yet to be tested.[31]

Table 1: Prospective rugby league epidemiological publications analysed by type of playing population for matches and training by country of origin.

Playing population level	Gender	Studies conducted on match injuries	Studies conducted on training injuries
Professional tournament	• Male	• None	• None
Professional match	• Male • Male	• England[116, 117, 119-122, 134, 137, 230] • Australia[114, 195, 197, 223]	• None
Semi-professional tournaments	• None	• None	• None
Semi-professional teams	• Male • Male	• Australia[74, 77] • New Zealand[153]	• Australia[76, 77, 80]
Sub-elite tournament	• Male	• None	• None
Sub-elite teams	• Male	• Australia[85]	• Australia[81, 97]
Amateur tournament	• Male • Female	• None • New Zealand[150]	• None • None
Amateur teams	• Male • Male	• Australia[69] • New Zealand[152, 169]	• New Zealand[151]
Masters tournament	• Male	• None	• None
Masters teams	• Male	• None	• None
School-level tournaments	• Male • Female	• None • None	• None • None
School-level team	• Male • Female	• None • None	• None • None
School-level tournaments	• Male • Female	• None • None	• None • None
Junior	• Male • Male • Female	• Australia[92, 213] • New Zealand[148] • None	• None • None • None
Sevens	• Male • Male	• Australia[73] • New Zealand[154]	• None
Competition	• Male • Male	• New Zealand[185]	• None
Review of injuries at various levels	• Male • Male • Male • Female	• New Zealand[169] • Australia[78, 141] • England[118] • None	• None • None • None • None

Injury definitions for rugby league

A fundamental process, and typically the first step for the injury prevention process, is ongoing injury surveillance.[57, 63, 196, 244] However, comparison of results from injury surveillance studies are often difficult due to the inconsistencies in the injury definitions utilised[57, 196] and the methodologies undertaken,[29, 57, 62, 123, 244] and therefore the results and conclusions obtained can often have important differences.[57, 62, 78, 87, 123, 137, 197, 244] To fully understand the extent and nature of rugby league injuries, it is necessary to consider the various injury definitions that have been used for collating and assessing rugby league injuries.

The definition of a sports injury is frequently discussed and, to date, there is no universally accepted definition of a sport injury.[29, 133, 155, 194] Sports injury definitions are typically provided as operational criteria for the recording and reporting of injuries rather than as a theoretical definition.[68] These definitions usually are broadly based around the concept that *"bodily damage caused by a transfer or absence of energy"* is what causes injuries to occur.[68] This concept is useful in clarifying whether an incident in rugby league should be recorded as an injury. Several team sports (cricket,[196] football/soccer[67] and rugby union[68]) have published consensus statements in an attempt to obtain more consistent and comparable results from studies undertaken in these sporting activities.

Studies on the incidence of injuries in rugby league are no different and have suffered from inconsistencies in the injury definitions utilised (see Tables 2-4).[123, 141] Variations reported for injury incidence are often the result of data obtained from a relatively small numbers of players and teams[118, 134] and, often over a limited time frame.[141]

Some studies on rugby league injuries (as shown in Tables 2-4) have utilised a criterion of a missed match as an injury definition,[84, 85, 92, 96, 114, 118, 119, 189, 193] total injury incidences[58, 69, 73, 76, 77, 80, 81, 137, 148, 150-154, 185, 206, 213, 223, 230] or a combination of both time-loss and non-time-loss injuries,[58, 76, 77, 79, 80, 137, 148, 150, 152-155, 206, 223] while other studies have incorporated a medical treatment injury definition.[195, 223] Consequently, the definition of an injury in rugby league has been widely discussed and disputed[133, 155, 194] and to date there is no uniformly accepted definition. The key issue in establishing the injury definition has been centred on what injuries should be actually recorded.

Studies have reported that up to 90% of sports injuries have been recorded as non time loss injuries.[205] This has been similar in some studies in rugby league where non time loss injuries have been reported to be between 85%[58] to 93%[80] of match injuries, and up to 98%[80] of training injuries. The inclusion of non time loss injuries has been reported to bias the reported data towards non time loss injuries and, as a result of this bias, head and neck injuries make up a large proportion of the total injuries in rugby league.[141]

The use of a time-loss definition directs attention to those injuries that are most likely to have direct consequences on players, their team and their club performance,[236] however, the use of this definition understates the effects that non-time-loss injuries have on the healthcare system.[134]

The time-loss definition also contains certain inaccuracies, such as an amateur player who trains only twice a week has a greater likelihood of recovering from an injury before the next training session than a sub-elite or elite level player who trains daily.[144] An injured player may also participate in a training session but the participation level may be restricted by the injury or they may be undergoing a modified training session.[144]

Recent attempts by researchers to establish a standard definition for rugby league injuries have been difficult[133, 155] as some researchers were not in favour of a definition that was all encompassing and enabled non-time-loss injuries to be recorded. The following definition of rugby league injury was eventually agreed to by all but two of the six researchers and is therefore suggested for use in forthcoming studies:

> *"Any pain or disability that occurs during participation in rugby league match or training activities that is sustained by a player, irrespective of the need for match or training time loss or for first aid or medical attention. An injury that results in a player requiring first aid or medical attention is referred to as a 'medical attention injury' and an injury that results in the player being unable to partake in full part of future training and/or match activities is referred to a 'time loss' injury."*[155]

An advantage of the all encompassing injury definition enables comparison between rugby union[68] and soccer[67] as the injury definitions are similar. The disadvantage is that there are possibly more transient / non missed match injuries recorded in rugby league and compliance with a broad injury definition may be limited. This was addressed with the recommendation that both total (all injuries recorded) and injuries that result in time loss/ missed match/training be reported, enabling inter-study comparisons to be undertaken in future research. For further information on the debate regarding definitions of injury please see Orchard and Hoskins[194] and Hodgson, et al.[133]

Definition of injury exposure and injury rate for rugby league

There is no set format for data collection for sports participation although the reporting of injury incidence in sports is becoming more standardised, enabling comparison of results between sporting codes[222] and different environments (e.g., training, appearances and competition). Studies involving all levels of rugby league participation[78, 87] have reported injury rates (see Tables 2-4) using both a denominator (number of athletes, games, appearances) and a numerator (exposure measure)[35, 135] expressed, for example, as injury rate per 1000 playing hours (IR per 1000 playing hours).

To calculate the injury risk exposure hours for a rugby league team, the number of players (NP=13) on the field at any time is multiplied by the game duration (GD= 80 minutes or 1.3 hours or less at different participation levels). The result is 17.3 player exposure hours (PEH) per team per game (13NP x 1.3GD = 17.3PEH). Game injury risk exposure hours (GIERH) for the team are calculated by multiplying the player exposure hours per team per game by the number of games (e.g., NG=23 games per season) (e.g., 13NP x 1.3GD x 23NG = 398GIERH).[35, 69, 72, 73, 76-80, 135, 136]

Table 2: Professional rugby league injury definitions used and the resulting average injury rate and rates for matches and training.

Reference	Level of participation	Total injury rate	Missed match/training injury rate	Injury definition used
Seward et al.[223]	Professional (8 teams, 3 grades, 1 year)	139 per 1000 player hours	44 per 1000 player hours	That which caused a player to be unavailable for selection in a match, or participation in a training session or any other injury which required specific medical treatment, other than routine conservative measures.
Gibbs[114]	Professional (1 club, 3 grades over 3 years)	-	45 per 1000 player game hours	That occurring during a game that caused a player to miss a subsequent match.
Estell et al.[58]	Professional (2 grades) and elite junior (4 teams) over 1 season	243 per 1000 player game hours	34 per 1000 player game hours	Pain, discomfort or disability arising during, or immediately after, as a result of, playing in a rugby league match.
Stephenson et al.[230]	Professional (1 club, 2 grades over 4 seasons)	114 per 1000 hours of match play	-	The onset of pain or a disability that occurred while playing rugby league football.
Hodgson-Phillips et al.[137]	Professional (1 team over 4 seasons)	346 per 1000 player hours	39 per 1000 player hours	Pain, discomfort, disability or illness (new or recurrent) that the player acknowledged after participating in a rugby league related activity / game.
Gissane et al.[118]	Professional (pooled data from 4 prospective studies: Seward,[223] Gibbs,[114] Stephenson,[230] Gissane[116])	-	40 per 1000 player game hours	That requiring a player to miss the subsequent game.
Gissane et al.[119]	Professional (1 club, 9 seasons)	-	46 per 1000 player hours	A physical impairment received during a competitive match that prevented a player from being available for selection to play in the next game.
Orchard[193]	Professional (1 club, 2 grades over 6 seasons)	-	40 per 1000 player hours	That requiring a player to miss a subsequent game.
O'Connor[189]	Professional (100 players from 13 clubs)	-	2 per 1000 player hours	An injury was recorded if there was: (a) pain and tenderness in the adductors or at the adductor bone-tendon junction; (b) pain and weakness on resisted adduction; and (c) the player was unable to complete training or a game and missed the following training session.
Orchard et al.[195]	Professional State of Origin from 2000 to 2006 (1 team, 3 games a year)	139 per 1000 player hours	44 per 1000 player hours	A match injury recurrence (for the State of Origin team) was defined as an injury to the same body part which had been medically assessed prior to the start of the match and which caused the player to miss subsequent games for his club after the Origin match

Table 3: Semi-professional rugby league injury definitions used and the resulting average injury rate and rates for matches and training.

Reference	Level of participation	Total injury incidence	Missed match / training injury incidence	Injury Definition used
Gabbett[76]	Semi-professional (60 players over 1 season)	27 per 1000 training hours	9 per 1000 training hours	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during a training session or immediately after the training session.
Gabbett[77]	Semi-professional (156 players over 2 seasons)	825 per 1000 playing hours	68 per 1000 playing hours	Any pain or disability suffered by a player during a match or training session, and subsequently assess by the head trainer during or immediately following the match or training session.
		45 per 1000 training hours	1 per 1000 training hours	
Gabbett[81]	Sub-elite (220 players, 3 years)	78 to 157 per 1000 training hours	19 to 33 per 1000 training hours	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during, or immediately following the training session.
Gabbett[80]	Semi-professional (79 players, 1 year)	106 per 1000 training hours	2 per 1000 training hours	Any pain or disability suffered by a player during a match or training session, and subsequently assessed by the head trainer during or immediately after the match or training session.
		917 per 1000 playing hours	65 per 1000 playing hours	
Gabbett[84]	Semi-professional (156 players, 2 seasons)	-	68 per 1000 playing hours	Any pain or disability suffered by a player during a match that resulted in the player missing a subsequent match.
Gabbett[85]	Sub-elite (1 sub-elite club over three competitive seasons [a = unlimited interchange, b=limited interchange])	-	73 per 1000 playing hours [a]	Any pain, disability or injury that occurred as a result of a competition game that caused the player to miss a subsequent game.
			51 per 1000 playing hours [b]	
Gabbett et al.[96]	Semi-professional (1 club, 153 players over 4 years)	-	55 per 1000 playing hours	Any pain, disability or injury that occurred as a result of a competition match that caused a player to miss a subsequent match.
King et al.[153]	Semi-professional (8 teams, 240 players, 1 year)	115 per 1000 playing hours	78 per 1000 playing hours	Any pain or disability suffered by a player during a match that required advice and/or treatment.

Table 4: Amateur rugby league injury definitions used and the resulting average injury rate and rates for matches and training.

Reference	Level of participation	Total injury incidence	Missed match / training injury incidence	Injury definition used
Norton et al.[185]	Amateur (24 teams over 1 season)	25 per 1000 hours of play 0.03 per 1000 hours of training	-	That which occurred during a match or training, for which medical attention was sought, or the player was unable to attend or take part in training or a match
Pringle et al.[206]	Amateur (1730 players age 6 – 15 yrs old over 1 season)	25 per 1000 player hours	10 per 1000 player hours	A minor injury was defined as one where the player was still in discomfort immediately after the game, but was able to play the following week. A moderate injury was defined as one that prevented the player from participating in the following week's game.
Raftery et al.[213]	Amateur (253 junior teams over 1 year)	10 per 1000 playing hours	-	Any incident which required medical or paramedical review, missed participation at one training session or non-participation in one game.
Gabbett[69]	Amateur (9 teams over 3 seasons)	161 per 1000 game hours	-	That which was subsequently assessed by the head trainer during or immediately after the match.
Gabbett[73]	Amateur (168 players, 3 rugby league sevens tournaments)	284 per 1000 playing hours	-	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during or immediately after a rugby league seven's match.
King et al.[154]	Rugby league 7's (semi-professional and amateur)	498 per 1000 playing hours	262 per 1000 playing hours	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King[148]	Junior (3 teams in U16 and 1 team in U18 competition)	217 per 1000 playing hours	129 per 1000 playing hours	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King et al.[152]	Amateur (1 team 50 players, 1 year)	701 per 1000 playing hours	194 per 1000 playing hours	Any physical or medical condition that occurred during participation in a rugby league match that required medical treatment or resulted in missed match participation.
King et al.[150]	Amateur women's tournament (5 teams over 3 days)	307 per 1000 playing hours	176 per 1000 playing hours	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King et al.[151]	Amateur training (1 team, 50 players, 1 year)	22 per 1000 training hours	17 per 1000 training hours	Any physical or medical condition that occurred during participation in rugby league training activities that required medical treatment or resulted in missed training participation.
Gabbett[92]	Junior rugby league (80 players over four competitive seasons)	-	57 per 1000 playing hours	Any pain or disability suffered by a player during a match that resulted in the player missing a subsequent match.

Definition of injury severity for rugby league

Assessment of sports injury severity is another aspect that has also not achieved consensus in the literature. A recommendation for classification of injury severity has been proposed that relates the injury severity to the amount of missed match or participation time as a result of the injury.[144] Although this classification has been used in the identification of injury severity, the time-loss difference has varied. For example, a minor injury has been classified as a loss of participation in sporting activities between one to seven days,[144] yet another time-loss classification for minor injuries has been up to 28 days.[107] The commonly used definitions for injury severity in rugby league studies (see Table 5) have been:

1. Transient (no games or training lost);
2. Minor (one game or training week missed);
3. Moderate (two to four games or training weeks missed); and
4. Major (five or more games or training weeks lost).

Table 5: Injury severity classifications for rugby league.

Author	Non-missed participation	Minor	Moderate	Major
King et al.[151, 153, 154]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	≥5 games/training weeks missed
Hodgson-Phillips et al.[134]	Transient (0 games missed)	1 game missed	2 to 4 games missed	≥5 games weeks missed
King[148]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	≥5 games/training weeks missed
Gabbett[69, 73, 76-78, 92]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	≥5 games/training weeks missed
Stevenson et al.[232]	-	Self care by participant	Health care professional	Assessed at a hospital
Hodgson-Phillips et al.[137]	Transient (0 games missed)	1 game missed	2 to 4 games missed	≥5 games or weeks missed
Sandelin et al.[219]	-	<1 week	1 to 4 weeks	≥4 weeks
Gibbs[114]	Transient (0 games missed)	1 game missed	2 to 4 games missed	≥5 games or weeks missed

In a recent endeavour to standardise the definitions for injury severity in rugby league,[155] two of the six researchers again did not agree with the inclusion of transient injuries.[133, 194] Although time-loss is identified as the 'gold standard' in reporting rugby league injuries, transient injuries still create an impact on the financial resources of teams and participation of players.[134, 161]

Previous injury epidemiological studies have identified that non-time-loss injury incidence can often account for between 72–95% of the total injuries that occur.[205] These injuries, despite not directly affecting the player's participation in matches, are important as they have a direct and indirect economic impact[134] through areas such as lost employment and associated rehabilitation costs. The following definition of injury severity in rugby league was eventually agreed to by all but two of the six researchers and is therefore suggested for use in forthcoming studies:

> *"Transient (no matches/training weeks missed), Minor (1 missed match/training week), Moderate (2 to 4 missed matches/training weeks), or Major (5 or more missed matches/training weeks)."*[155]

For the purpose of studies in rugby league, a transient injury is defined as *"any injury that causes a player to seek medical or first aid treatment during or after a rugby league activity but does not lead to loss of further participation or non-selection for matches".*[155] These include injuries that are ongoing but not of sufficient severity to prevent the player from participating in match activities or being selected for match participation.

Classification of injury site and injury type for rugby league

Ideally the classification of injuries should not only include type and location of the injury but also differentiate between trauma induced injuries and those that occur from overuse or overexposure to a causative agent.[144] For example, Van Mechelen[244] suggested that an acute type injury is caused by a single event that causes macro-trauma. If the injury is caused as a consequence of exposure to repetitive micro-traumas then it should be classified as an overuse injury. Literature specific to rugby league has categorized injuries according to both site using anatomical location,[69, 72, 73, 75, 78, 123, 213, 235] and by type (see Table 6)[5, 69, 72, 73, 76, 78, 79, 81, 87, 115, 123, 213, 235] but whether the injuries are acute or overuse has not been explicitly stated. Suggested injury type definitions for rugby league are provided in Table 6.

Table 6: Injury type definitions for rugby league.

Concussion: A traumatic injury to the brain as a result of a violent blow, shaking, or spinning resulting in a transient neurological dysfunction.	Fracture: A break in bone or cartilage, usually the result of trauma. Fractures are classified according to their character and location. Stress fractures result from overuse.
Dislocation: Complete dislocation of a joint also termed a luxation. A partial dislocation is a subluxation. Dislocations result from trauma.	Laceration: A cut or any break in the skin integrity caused by trauma.
Sprain: An injury to a ligament that results from overuse or trauma. Sprains occur when there is a stretch or tear in one or more ligaments (slightly elastic bands of tissue that keep the bones in place while permitting movement at a joint).	Strain: An injury to a tendon or muscle resulting from overuse, trauma or overexertion.
Bruise/Haematoma: or "contusion" is a traumatic injury of the soft tissues resulting in breakage of local capillaries and leakage of red blood cells. It can be seen as a reddish-purple discoloration that does not blanch when pressed upon.	Other: All other medical conditions not incorporated with any of the definitions previously identified.

Match versus training rugby league injuries

Injury rates for rugby league matches and training

The majority of injuries occur in the match environment with rates typically increasing as the playing level increases.[78] Junior rugby league injury rates ranged from 1[213] to 197[148] per 1000 playing hours and increased proportionately with the participation level.[213] Amateur match injury rates were slightly higher ranging from 134 to 701 per 1000 playing hours[75, 76, 78, 87, 114, 116, 119-121, 152, 230] while semi-professional participation injury rates were higher still ranging from 115[149, 153] to 825[77, 78] per 1000 playing hours. However, professional level injury rates were less than semi-professional ranging from 58[246] to 211[58] per 1000 playing hours.

Only a few studies have reported training injuries in rugby league[76-78, 80, 87, 120, 137] where injury rates (12 to 89 per 1000 training hours) were reported to be less than match injuries.[78, 87] There have been no studies undertaken on junior rugby league training injuries.[78] Amateur training injury rates have been reported to be 22 per 1000 training hours[151] while semi-professional / sub-elite training injury rates have been reported to occur between 27 to 89 per 1000 training hours.[76, 77, 87] Professional training injury rates are reported to be less at 12 per 1000 training hours.[137]

Some studies indicated a reduction in training injury rates with an alteration in training methods[80, 81, 87] and the majority of training injuries were reported as transient (44 per 1000 training hours).[79]

Incidence of severe injuries in rugby league matches and training

Severe injuries occurring in rugby league matches have been identified as those causing the player to miss five or more subsequent matches[69, 72, 76, 78, 79, 81, 87, 96, 118, 123, 137, 213] and have been associated with players' biological maturity, playing intensity and skills.[75, 213] Approximately 16 to 30% of all rugby league injuries have been reported as severe resulting in players missing five or more matches, and therefore the injury rate is high.[72, 77, 87, 96, 114, 137] These high rates of severe injury place demands upon other team members and, if the player returns to playing too early, places them at an increased risk of further injuries.[96]

Amateur match severe injuries have been reported to occur at an injury rate of 27 per 1000 playing hours.[72] Recognizing that a rugby league match is 35 playing hours in duration (13^{NP} x1.3^{GD} x 2^{NT} (Number Teams) x 1^{NG}), a severe match injury could occur approximately once in every match. Semi-professional severe match injury rates have been recorded at 68 per 1000 playing hours,[77, 87] while in professional rugby league, severe match injury rates have ranged from 34 to 52 per 1000 playing hours[58, 87, 114, 118, 120, 137, 223] meaning there is the risk of a severe match injury every game.

Differences in the reporting of match severe injury rates between the different participation levels may be due to the unavailability of specialized medical staff at the event or through the club facilities.[77, 87] Amateur teams may not have direct access to medical services[72, 87] whereas semi-professional teams may have a physiotherapist and/or team physician present when they play.[77, 78] At the professional level of participation, all teams have direct and full access to specialized rehabilitation services through their club.[72] Another reason for the lower injury rates in professional teams could be the under-reporting of injuries due to the pressure to return to play,[77, 78] especially if players risk losing their place in the team or if a financial reward occurs as a result of their participation.[77]

A further aspect of match severe injuries is the socio-economical impact.[72, 78, 87, 182] Significant long-term career limitations, medical costs and loss of income have been associated with major match injuries.[72, 78, 87, 182] Gabbett[72] identified the mean respective costs associated with severe match injuries as $A75 (2001) (medical expenses) and $A205 (wages lost) per playing injury.

Meir et al.[182] also reported long-term job limitations, loss of income and medical costs associated with professional rugby league related match injuries, but did not specify a figure.

Severe injuries in training are uncommon,[78] with amateur training severe injury rates reported to be 16.9 injuries per 1000 training hours while semi-professional training were 1 injury per 1000 training hours over two years.[76, 77, 87] Professional training was similar with 1.4 injuries per 1000 training hours reported.[137] However, there were no reported training-related severe injuries in junior or amateur rugby league.[78, 87, 96]

Site and type of rugby league injuries during matches and training

Early research in rugby league identified that ligament and joint injuries (54%) were the common injuries[114] and occurred primarily to the knee (24%).[114] More recently studies have shown a change in anatomical sites being injured at all levels of participation (see Table 7), where the common injury sites were to the head and neck.[6, 7, 69, 73, 77-80, 87, 116, 135, 137, 223, 230] The changes in injury site were thought to be due to changes in the match rules in recent years (i.e., defensive line back to 10 meters, ball stripping in the tackle).[69, 78] Recently published research has identified that the shoulder is now the common reported injury site.[92, 149, 153]

One study on semi-professional players[77] reported that haematomas (271 per 1000 playing hours) and injuries to the calf and thigh (168 per 1000 playing hours) were the common type and site of injuries.[77, 87] This is in conflict with another semi-professional study where strains (28 per 1000 playing hours) and injuries to the shoulder (16 per 1000 playing hours) were the common injury type and site of injuries reported.[149, 153] Injuries to other anatomical sites were higher for the Australian than the New Zealand studies (face 115[77, 87] vs. 9[149, 153] per 1000 playing hours; arm and hand 115[77, 87] vs. 13[149, 153] per 1000 playing hours; knee 109[77, 87] vs. 15[149, 153] per 1000 playing hours; and the head and neck 104[77, 87] vs. 14[149, 153] per 1000 playing hours).

Table 7: Site, type and cause of common rugby league match injuries.

Study	Playing level	Injury site	Injury type	Injury cause
Alexander et al.[6]	Professional	Head & neck	Haematomas & strains	
Alexander et al.[7]	Professional	Head & neck	Contusions	
Gibbs.[114]	Professional	Knee	Ligament & joint	
Gissane et al.[118]	Professional	Lower limb		
Gissane et al.[120]	Professional	Head & neck	Haematomas & strains	Being tackled
Gissane et al.[116]	Professional	Head & neck	Haematomas & strains	Being tackled
Gissane et al.[121]	Professional	Head, neck, knee & shoulder	Joint sprains	Being tackled
Hodgson-Phillips et al.[137]	Professional	Knee	Haematomas & strains	
Seward et al.[223]	Professional	Head & neck	Lacerations & contusions	
Stephenson et al.[230]	Professional	Head & neck	Haematomas & strains	Being tackled
King et al.[153]	Semi-professional	Shoulder	Haematomas & strains	Being tackled
Gabbett.[77]	Semi-professional	Thigh & calf	Haematomas & strains	Being tackled
King et al.[152]	Amateur	Thigh & lower leg	Haematomas & strains	Being tackled
King et al.[150]	Amateur women	Knee & lower leg	Haematomas & strains	Physical collisions
Gabbett.[69]	Amateur	Head & neck	Haematomas & strains	
Gabbett.[72]	Amateur	Arm & hand	Joint sprains	While tackling
Gabbett[92]	Junior	Shoulder	Sprains	Being tackled
King[148]	Junior	Knee & shoulder	Sprains & strains	Being tackled
Raftery et al.[213]	Junior	Knee	Fractures	Being tackled

Junior rugby league injuries differed in injury site.[87, 213] Although the lower limb (knee 14% and ankle 13%)[87, 213] was the frequent injury region reported previously, the shoulder (28%) has now been reported to be the common injury site.[92] Injuries to the head and neck occurred in 11% of all junior amateur injuries,[87, 213] and fractures have become common, especially in players aged between 6–17.[87, 213] Changes in defensive strategies, levels of participation and anthropometric aspects of players have been attributed to the differences in injury sites.[69, 78]

Lower limbs incur the majority of injuries in training for semi-professional players,[76, 77, 87, 137] with the calf and thigh the commonly recorded injury site.[76-78, 87, 137] Lower limb strain injuries have been reported to be directly related to an increased need for players to be able to rapidly accelerate, decelerate and change direction.[78, 87, 179] The type of training injuries recorded may reflect the emphasis on game-specific skills and increased playing intensity required.[77, 78, 80, 81, 87, 96] The majority of semi-professional training injuries (91 per 1000 training hours) occurred in traditional conditioning activities such as running, sprints,[76] while skill-based conditioning games (ball handling, inter team games) incurred less injuries (9 per 1000 training hours).[76, 87]

The common training injury type for semi-professional participants were muscular strains (137 per 1000 training hours).[76, 77] Other injury causes were overuse (20 per 1000 training hours), fall or stumble (14 per 1000 training hours) and collision with another player (14 per 1000 training hours).[80] Gissane et al.[120] reported similar findings for professional rugby league players in the

UK, but there has been no research published on training injuries in the National Rugby League (Australia and New Zealand) to enable comparison.

Professional injuries were similar to semi-professional injuries,[78, 87, 114] with the most frequent injuries (38 per 1000 playing hours) to the head and neck.[230] Other anatomical areas (thigh and calf 20 per 1000 playing hours; knee 12 per 1000 playing hours; thorax and abdomen 10 per 1000 playing hours) occurred less frequently.[78, 114, 230] Muscular injuries were the most frequent injury type (34 per 1000 playing hours),[230] while joint sprains (27 per 1000 playing hours)[230], lacerations (20 per 1000 playing hours)[223, 230], and muscle strains (18 per 1000 playing hours)[230] occurred less frequently.

Cause of rugby league injuries during matches and training

Studies have identified that the tackle is the major cause of injuries in rugby league matches.[72, 77, 87, 96, 116, 120, 121, 123, 213, 230, 246] Between 46-90% of all injuries that occurred in matches were tackle related,[72, 77, 87, 116, 120, 121, 123, 213, 230, 246] with all concussions recorded resulting from the tackle.[78, 87] However, high rates of concussion could be expected given each player was involved in an average of 41 physical collisions per match.[116, 117, 120, 122, 123] Research into amateur rugby league also identified the tackle as the most frequent cause of injuries,[69, 72, 73, 152] with injury rates from the tackle reported to be as high as 538 per 1000 playing hours.[152] Injuries were more prominent to the ball carrier (405 per 1000 playing hours) than the tackler (133 per 1000 playing hours).[152] Junior rugby league had a lower injury rate but was similarly prominent to that in amateur rugby league.[92, 213]

Research into semi-professional matches also demonstrated that injuries occurred frequently during the tackle (95[149, 153] to 382[77, 87] per 1000 playing hours). The tackler sustained more injuries than the ball carrier (27%[77, 87] to 44%[149, 153] vs. 20%[77, 87] to 39%[149, 153]), which is the reverse of the trend seen in amateur,[77] and professional rugby league[116, 230] where the ball carrier sustained more injuries (46.3 per 1000 playing hours) than the tackler (21 per 1000 playing hours).[116, 230]

Injuries resulting from the tackle in professional matches increased when the competition format was changed from a winter to a summer competition,[119, 137] where the rate of tackled player injuries increased from 16 to 30 per 1000 playing hours.[119, 137] The tackling player's injury rate also increased from 6 to 14 per 1000 playing hours.[119, 137]

Type of player injured during matches and training - Forwards versus backs

Early research on rugby league injuries identified that there were no differences between forwards and back injury rates during matches.[114, 116] However, more recent research identified forwards have a higher injury rate than backs,[6, 78, 87, 96, 164, 180, 182, 230] which possibly reflects the forwards' greater involvement in physical collisions.[6, 87, 96, 164, 180, 182, 230] Forwards recorded between 55 to 139 injuries per 1000 playing hours for tackle-related injuries[116, 117, 121, 230] while backs had a slightly lower tackle-related injury rate (29 to 93 per 1000 playing hours).[116, 117, 230]

Injury rates have also been studied in defensive and attacking roles in a professional competition.[117] In attack, the injury rates of forwards were higher than backs (16 per 1000 playing hours vs. 13 per 1000 playing hours)[117] and their injury rate increased substantially when in a defensive role (forwards 39 per 1000 playing hours vs. backs 16 per 1000 playing hours).[117] With seasonal changes, positional injury rates changed in both forwards (Winter 35 per 1000 playing hours vs. Summer 68 per 1000 playing hours) and backs (Winter 26 per 1000 playing hours vs. Summer 54 per 1000 playing hours).[87, 114]

Participation in other levels of rugby league (semi-professional and amateur) has also shown higher injury rates in forwards than backs.[69, 72, 73, 77, 78, 87] Forwards also had higher rates of head, neck, face and knee injuries than backs in all competition levels[69, 78] whereas backs had a higher injury rate in the ankles and 'other' site categories than forwards.[69, 78]

Studies of semi-professional players identified that forwards had a higher incidence of training injuries compared to backs,[77, 78, 87] with an injury rate of 53 per 1000 training hours compared with 38 per 1000 training hours for backs.[77, 78, 87] Forwards also had a higher injury rate to the head and neck, shoulder, thigh and calf, ankle and foot when compared to backs.[77, 87] During the early part of the season, the forward injury rate was 70 per 1000 training hours while backs recorded an injury rate of 48 per 1000 training hours.[77, 87] Injury rates decreased for all players by late season, with forwards recording 35 injuries per 1000 training hours while the backs recorded 28 injuries per 1000 training hours.[77, 87] The common training injury types were muscular strains and overuse injury.[77, 87] Forwards recorded more muscular strains (24 per 1000 training hours) than backs (15 per 1000 training hours)[77, 87] and more overuse injuries (12 per 1000 training hours) than backs (6 per 1000 training hours).[77, 87] However, there was no position-specific training injury research for amateur, junior or professional rugby league.[77, 87]

Time of injury during matches and training

There were limited studies into the timing of injuries during matches.[78] Gabbett[69] reported significantly more injuries in the second (71%) than the first half (29%) in amateur competition[69, 87] which was reversed in semi-professional[77, 78, 87] with more injuries in the first than the second half of matches (1014 per 1000 playing hours, 62% vs. 636 per 1000 playing hours, 39%).[78, 87] Professional competition was reportedly similar to semi-professional competition in that most[87, 223] but not all[153] studies reported more first half injuries (57%). There have been no junior rugby league studies evaluating injury occurrence in relation to time of injury.[78, 87]

The only study on the time of injury during training was for semi-professional rugby league.[77, 87] Teams often integrate skill and conditioning sessions in the later stages of the training session to simulate game related conditions promoting skill development under fatigued conditions[78, 79] and injury occurrence has been reported to be higher in the later stages of the training session,[77, 78, 80, 87] a finding that may be related to fatigue.[78, 79, 87]

Seasonal variations for match and training injuries

Traditionally the rugby league season runs from late summer through to early spring.[119, 121, 137] In the southern hemisphere this is from April to September[72] while in the northern hemisphere this is from August to April.[116, 119, 137] Early research undertaken in Australia[58, 114, 223] reported a higher injury rate than that reported in England[120, 121, 230] and this was thought to be due to harder surfaces and higher temperatures.[119, 230] In 1996 the northern hemisphere competition season changed requiring players to have a shortened winter season before a compressed summer season.[119, 121, 137] This change exposed players to higher temperatures and harder grounds in conditions similar to those experienced in the southern hemisphere.[119, 121, 137] As a result the injury rate doubled from 367 (winter) to 617 per 1000 playing hours (summer).[137] The type of injures remained the same but the risk to the tackler had increased twofold.[119, 137]

Traditional winter rugby league injury rates have been reported to fluctuate throughout the season[69, 75, 76, 78, 87, 114, 116, 119-121, 230] with amateur match injuries reportedly occurring more in the latter half of the season.[69, 78, 87] In one study[69] the injury rate was 134 per 1000 playing hours at the start of the season (March), declined in April but then increased progressively from May to September, culminating at 196 per 1000 playing hours[69] at the end of the season. The increasing injury rate was attributed to player fatigue and accumulative microtrauma[69, 78, 87] while other factors reported to have an influence on injury rates were environment changes and changes in ground hardness near the end of the season.[78, 87, 192]

Studies of semi-professionals have identified a similar trend in injury rates increasing from 561 to 1,339 per 1000 playing hours that was consistent for all playing positions.[77] The increasing injury rate was attributed to playing intensity as the final series approached,[77, 87] a concept supported by Gabbett[80] who reported a significant correlation (r=0.74) between match injury rates and match intensity.[80, 87] Studies of professional rugby league players have also identified similar trends[78, 137] of increased injury rates as the season progressed.[7, 137] Injury severity also increased when the northern hemisphere season changed to a shortened winter season before a compressed summer season. Other studies have identified a slight variation with more injuries at the beginning of the season,[120, 223] with a decrease midseason before rising towards the final series.[120]

During the training pre-season period (December to April in Australia) the injury rate was 157 per 1000 training hours in 2001[81, 87] which reduced to 78 per 1000 training hours in 2003 as a result of changing training methods from traditional conditioning activities to game-specific skill-based conditioning games.[81, 87] Injury rates were noted to increase from December to March[81, 87] with the highest injury rate recorded yearly in February with an average of 142 per 1000 training hours.[81, 87] This rate decreased in March, prior to the season starting, and was identified as the result of an alteration in the training intensity.[81, 87]

Training injury rates through the season (April to September in the southern hemisphere) have been recorded to be highest early in the season (116 per 1000 training hours[77, 78, 87]) which is reportedly 3 times higher than the season average rate of 45 per 1000 training hours.[77, 78, 87] Training injury rate decreased as the training intensity decreased throughout the season.[77, 87] The high injury rate at the beginning of the season was significantly correlated (r=0.86)[78] to the increased training loads[77, 78, 87] which suggests that more injuries occurred when players trained harder.[77, 78, 80, 87] Professional training injuries were recorded at 12 per 1000 training hours[137] and a similar injury rate for training injuries over a season (1990-91) was reported for a professional team in England.[120] However, studies on professional rugby league[120, 137] participation have not identified details of the type of training injuries.

Conclusions

This systematic review of rugby league injuries reported the extent of injuries that occur in all levels of participation for matches and training. The majority of injuries occurred in the match environment with injury rates increasing as playing level increased. Early research in rugby league identified that ligament and joint injuries were common for match injuries, head and neck injuries were common during senior rugby league, and knee injuries were common at junior levels of participation. Recent research reported the shoulder as the common injury site in matches with lower limb muscular strains common for training injuries. Muscular injuries were common injury types for senior rugby league players while fractures were common for junior levels of participation. Being tackled as the ball carrier was the common cause for injury at all levels of participation levels in matches. Forwards were more likely to be injured in the tackle and had higher rates of head, neck, face and knee injuries than backs in all match and training competition levels. More injuries occurred in the second, than the first half of amateur matches but this was reversed in semi-professional matches. Fatigue was reported to influence the injury incidence in both match and training environments suggesting that changes in playing and training intensity may have contributed to injury.

Although comparisons between different participation levels have been reported in the literature, there is a paucity of studies looking at the different divisions in these participation levels (i.e. Division 1 and Division 2 amateur participation) and the injury incidence. Studies utilising single clubs or teams over a short period provide a snap shot of the injury incidence but do not address the breadth of participation nor do they reflect the different conditions seen in the various countries where rugby league is played. Also not addressed in the literature is how much fitness is a protective factor when comparing injury incidence at the different levels of participation.

Ongoing review of the different levels of participation enables an epidemiological perspective to be established of the injuries in rugby league. The change in the injury site and type reported in the research literature is reflective of the changing match and training styles seen in the modern game of rugby league. Changes in injury site and type could be used to prompt further research and development of injury reduction programs to readdress the issue of injuries that occur as a result of participation in rugby league activities. Further research is warranted at all participation levels of rugby league in both the match and training environments to confirm the strongest risk factors for injury. In particular specific research is warranted on the leading cause of injuries reported in rugby league, the tackle in both the match and training environments. Sports medicine practitioners should be cognisant of the extent and nature of rugby league injuries and work with coaches, athletes and trainers to prevent these injuries occurring.

CHAPTER 3: A REVIEW OF THE PHYSIOLOGICAL AND ANTHROPOMETRICAL CHARACTERISTICS OF RUGBY LEAGUE PLAYERS

This chapter comprises the following paper accepted by *South African Journal for Research in Sport, Research and Recreation:*

Reference

King, D.A., Hume, P.A., Milburn, P. & Guttenbeil, D. A review of physiological and anthropometrical characteristics of rugby league players. *South African Journal for Research in Sport, Research and Recreation.* 2009. **31**(2):49-67.

Author contributions

King, D. 86%; Hume, P. 10%; Milburn, P. 2%; Guttenbeil, D. 2%

Overview

The aim of this study was to determine the anthropometric and physiologic characteristics of rugby league players based on a review of literature. Searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases were performed for studies published in English from 1948 to May 2008. Terms utilized for the search of relevant research studies included *anthropometric, physiologic, rugby league.* Qualifying studies were mainly uncontrolled descriptive trials. Outcomes were body mass, sum of skinfolds, muscular power, speed, agility and estimated maximal aerobic power of rugby league players. Excess body fat has a detrimental effect on players' sporting performance. Forwards have a higher body mass than backs in most, but not in all published studies. Amateur forwards had a higher estimated body fat percentage (20%), lower body mass (91 kg), lower vertical jump height (38.1 cm) and lower estimated VO_{2MAX} (38.1 $ml \cdot kg^{-1} \cdot min^{-1}$) than semi-professional and professional players. Anthropometric and physiologic capacities of rugby league players and the physiologic demands of rugby league participation generally increase as the participation levels increase. However, there is evidence that player physiologic capacities may deteriorate as the season progresses. This has been shown to occur with increases in skin fold thickness and some decrement in players' maximal aerobic power and muscular power over a season.

Introduction

Rugby league is an international team sport that consists of 13 players in each team. Junior and amateur rugby league matches are typically played under an unlimited interchange rule whereas professional/elite and semi-professional/sub-elite rugby league teams utilise up to 12 interchanges in competitions. Each team is permitted six tackles with the ball for a set of play and they must advance down the field into the opposition's territory and score a try.[87, 104] The ball must be passed backwards but can be carried or kicked forward into the opposition's territory.[87, 118] At the completion of the six tackles, the ball is immediately given to the opposition team to commence their set of six tackles.[87, 114] The same players are therefore involved in both attack and defence.

The game is played under different rules depending upon player age. Children aged less than nine years play under mini-modified rules requiring play on a half sized field. There is no tackling, no kicking of the ball and no scrums contested in this age group.[43] Children between 10 and 12 years old also participate in a modified rules version of the game that requires matches to be played on three-quarter sized fields. Tackles are allowed, there is limited kicking and they can contest for the ball in a scrum as in the full version of rugby league.[43] For players over 13 years, the game is played under the international rules.

Similar to rugby union, the rugby league team consists of two main groups of players (six forwards and seven backs) on the field and four reserves that can be interchanged at the coach's discretion.[37, 84, 183] The demands on the players vary according to the specific positions played[37, 84, 122, 183] with forwards (prop n=2, hooker n=1, second row n=2 and lock n=1) more predominately involved in large numbers of physical collisions and tackles.[78] Backs (half-back n=1, stand-off n=1, centre n=2, wing n=2 and fullback n=1) spent more time in free running but were also involved in tackles and collisions.[78] There are four subgroups reflecting positional commonality are props, hookers and halves, back-rowers and outside backs.[37, 104, 183]

As a result of the physical requirements and intense nature of the game, musculoskeletal injuries were common.[77, 87, 104] Player's competing in rugby league often undergo frequent bouts of high intensity activity (e.g., tackling, sprinting, running and passing) interspersed with short bouts of low intensity activity (e.g., jogging, walking and standing).[27, 44, 104, 180] As a result of the intermittent nature of the game, the physiologic demands of rugby league are complex. Players are required to have maximal aerobic power, speed, muscular strength and power and agility developed appropriately to be able to compete in the match environment.[27, 44, 104, 180]

Rationale for review

Brewer and Davis[27] originally published a review on the applied physiology of rugby league players in 1995. Since then there have been changes in the rules of rugby league,[181, 198] development of new training techniques[76] and more studies on the physiology of rugby league participants.[101, 103, 104] The purpose of this paper was to present the available research in a comprehensive review further complimenting the already available studies on the applied physiology of rugby league.

Objective

To investigate the anthropometric and physiologic characteristics of rugby league players based on a review of the current literature.

Methods

Searches of PUBMED, CINHAL, OVID MEDLINE, SCOPUS, and SPORTDISCUS databases were performed for studies published in English up to and including May 2008. The computer databases provided access to sports-oriented and biomedical journals, serial publications, books, theses, conference papers, and related research published since 1948. Terms utilized for the search of relevant research studies included *anthropometric, physiologic, rugby league.* Qualifying studies were mainly uncontrolled trials. Outcomes were body mass, sum of skinfolds, muscular power, speed, agility, and estimated maximal aerobic power of rugby league players. All studies reported are on male rugby league participants unless otherwise stipulated.

Findings

Twenty-six published studies have reported anthropometric and physiologic aspects of rugby league players (see Table 8). Changes in the rules of rugby league have resulted in changes in the physiologic demands placed on players.[85, 198] Changes such as the move from a five metre (5-m) to a 10-m defensive line following each tackle[181] and the introduction of the limited interchange replacement rule[85, 198] have required different training techniques and increased aerobic, strength, endurance and anaerobic requirements.[181]

Body composition

Meir et al.[183] showed that excess body fat and body mass had a detrimental effect on player sporting performance in areas such as aerobic capacity, thermoregulation and power to body mass ratio.[183] When comparing rugby league players to other team sports players from Australian football, soccer and rugby union, rugby league players had a higher body mass and percentage of body fat.[104]

Table 8: Anthropometric and/or physiologic assessments of rugby league players by participation level and country.

Playing population	Pre-season	Season duration
Professional	• England[10] • Australia[11-15, 18, 95, 186]	• None
Female teams	• Australia[91]	• None
Semi-professional teams	• England[10] • Australia[28, 44, 74, 95, 103] • New Zealand[149]	• None
Sub-elite teams	• Australia[11, 12, 14, 70, 75, 88-90, 101]	• None
Amateur teams	• Australia[70]	• Australia[82]
Masters teams	• None	• None
School-boy teams	• Australia[14]	• None
School-girl teams	• None	• None
Junior elite	• Australia[75, 88, 98, 102]	• None
Junior	• Australia[14, 83]	• Australia[86]
Reviews	• Australia[27, 87, 104]	• None

Although amateur level players had a percentage of body fat 31% higher than professional level players,[87, 104] the estimated percentage of body fat (calculated using the sum of four skinfolds[55]) and mean body mass measurements between forwards and backs were similar at all levels of participation.[28, 70, 83] Although amateur players' body mass has varied,[87, 104] when comparing the different participation levels there have been no significant differences observed in the mean body mass between forwards and backs (see Table 9).

Forwards had a higher body mass than backs in most,[164, 230] but not all[180] published studies. Body mass was the only physical characteristic that predicted selection into a first grade team[87, 104] or to be a forward or back.[87, 104] The requirement for forwards to spend more time involved in physical collisions[87] and tackles[87, 104] than backs may be reflective of the higher body mass and percentage of body fat recorded in this group.[214]

A higher body mass may also assist forwards in the development of greater impact forces associated with match participation[75] and may act as a means of protection from impact injuries.[98] However, no scientific evidence exists to refute or support this.[91] There have been no studies evaluating body compartment models for body composition characteristics (i.e., bone mass, fat mass, muscle mass, and residual mass), nor proportional anthropometric characteristics using the Phantom stratagem and predication of performance.

Table 9: Comparison of mean estimated body fat percentages (±SD) and body mass (±SD) or 95% CI amongst different participation levels in rugby league.

	Estimated body fat (%)				Body mass (kg)			
	Forwards		Backs		Forwards		Backs	
	Mean	±SD	Mean	±SD	Mean	±SD or 95% CI	Mean	±SD or 95% CI
Professional[28]	15.2	3.4	12.6	3.2	92.1	10.4	79.8	8
Semi-professional[83]	17.6	4.4	15.2	4.1	-	-	-	-
Semi-professional 1st grade[74]	-	-	-	-	97	10	88.7	7
Semi-professional 2nd grade[74]	-	-	-	-	89	13	84	7
Female elite[91]	-	-	-	-	75.5	12.5	64.7	7.6
Amateur[70]	19.9	3.7	17.5	5	90.8	86.2-95.4	79.7	74.7-84.7
Junior elite[98]	-	-	-	-	85.4	82.3-88.5	73.3	70.3-76.3
Junior sub-elite[98]	-	-	-	-	78.1	74.3-81.9	66.5	63.8-69.2

Anaerobic endurance

As rugby league is characterised by intermitted efforts of low to high-intensity activity that uses both the aerobic and anaerobic pathways[27] these are important criteria for performance in rugby league[10] and are utilised during repeated short-term explosive efforts such as tackling, sprinting and scrummaging.[27, 181] The demands of completing repetitive 10-m movements up and back, and tackling the opposition player to either a standstill or wrestling them to the ground, for six or more tackles in rugby league can place a high demand on the players' anaerobic glycolytic system.[138] Despite the requirements of anaerobic capacity in rugby league, anaerobic endurance is not currently systematically assessed in rugby league players.[138]

Video analysis has identified that the mean ±SD number of tackles made per defensive set in a match ranged from 3.7 ±1.5 to 4.0 ±1.2 for professional players and 3.3 ±1.8 to 3.4±1.5 for semi-professional players.[138] The mean time spent in a defensive set range from 37.0 to 47.0 seconds (professional 38.1 ±15.3 s to 46.9 ±13.6 s, and semi-professional 37.1 ±15.1 s to 38.3 ±18.5 s).[138]

Based on these performance demands, the triple 120-m shuttle test (T120S) was designed to evaluate the anaerobic system by mimicking the action of a defensive set.[138] The test requires completion of a set of six 10-m sprints combined with three simulated tackles. This test enables assessment of anaerobic endurance simulating tackles without the actual potential for injuries associated with tackling. The results were similar to video analysis of match data indicating that the average time in a defensive set was 42.5 ±1.7 s to 49.5 ±2.1 s.[138]

Maximal aerobic power

Maximal aerobic power (VO_2max) was reflective of the level of “cardiorespiratory” or “endurance fitness” of the participant.[238, 239] VO_2max of professional players is higher than that of other participation levels and is obvious when considering that professional players train upwards of five to six times a week and may perform multiple training sessions per day.

Table 10: Estimated maximal aerobic power (VO_2max) comparisons of forwards and backs between different participation levels.

	Forwards		**Backs**	
	VO_2max	±SD	**VO_2max**	±SD
Professional[75]	56.4	-	55.4	-
Semi-professional 1st grade[75]	45.8	4.4	48.0	3.6
Semi-professional 2nd grade[75]	45.6	4.9	44.9	4.2
Semi-professional[83]	50.5	4.8	54.1	4.3
Elite female[91]	32.2	4.4	35.3	3.4
Sub-elite 1st Grade[75]	50.0	2.4	50.1	2.7
Sub-elite 2nd Grade[75]	45.5	2.7	45.0	3.5
Sub-elite U19[75]	43.9	3.6	46.1	3.8
Sub-elite U16[75]	42.9	2.8	49.5	3.1
Sub-elite U15[75]	38.5	3.0	41.4	2.7
Sub-elite U14[75]	40.5	5.0	40.8	3.8
Sub-elite U13[75]	32.1	2.5	36.2	2.4
Amateur[75]	38.1	2.7	40.0	2.2

VO_2max expressed as ml.kg-1.min-1

Table 11: Estimated maximal aerobic power (VO_2max) comparisons between different playing positions in rugby league.

Level	Prop		Hooker		Second Row		Lock		Half-Back		Five-eighth		Centre		Wing		Fullback	
	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range
Semi-Professional[149]	48.33	-	48.94	-	55.42	-	51.44	-	55.42	-	51.73	-	55.14	-	54.57	-	55.42	-
Sub-elite[88]	42.6	±6.5	46.7	±7.0	44.4	±6.9	46.1	±5.4	47.3	±6.2	45.5	±5.3	46.6	±6.2	45.2	±6.7	47.0	±5.8
Junior[83]	42.2	-	46.9	-	45.1	-	44.6	-	50.5	-	48.3	-	47.1	-	45.7	-	47.8	-

VO_2max expressed as ml.kg-1.min-1

Amateur players had a poorly developed maximal aerobic power[187] - between 20% to 42% lower than professional rugby league players' estimated mean VO_2max,[28] and was attributed to a low playing intensity, infrequent matches of short duration and an inadequate training stimulus.[74] A higher percentage body fat may also contribute to the lower estimated mean VO_2max at this level of participation.[70] When comparing positional VO_2max differences of rugby league players, backs and forwards were similar suggesting that positional fitness training was similar for all playing positions (see Table 10). A study on sub-elite under 16 year-old rugby league players identified that backs had a significantly higher mean VO_2max (49.5 ml.kg-1.min-1) than forwards (42.9 ml.kg-1.min-1)[75] and the volume and intensity of training differed between forwards and backs in this age group of players.[75] Despite the similarities between forwards and backs at amateur, semi-professional and professional levels of participation, when different positional groups in rugby league were compared, they had significantly different estimated mean VO_2max scores (see Table 11).

Only a few studies have documented changes in VO_2max of characteristics over a competitive season (see Table 12) and have shown that the greatest improvements occurred in the early stages of the season but deteriorated towards the end of the season.[82, 86] This deterioration has been suggested as a result of decreased training loads, increased match loads and high injury rates,[82, 207] along with a high overall playing intensity and residual fatigue associated with limited recovery time between matches.[82]

Table 12: Estimated maximal aerobic power (VO_2max) changes over a competitive season for amateur and junior players.

	Amateur[82]		**Junior[86]**	
	Training		**Training**	
	VO_2max	**95% CI**	**VO_2max**	**95% CI**
Off season	42.0	(38.8 to 45.1)	43.7	(39.9 to 47.5)
Pre season	48.5	(46.1 to 50.9)	50.6	(48.5 to 52.8)
Mid season	51.3	(49.6 to 52.9)	53.5	(51.7 to 55.3)
End season	49.6	(47.5 to 51.7)	52.1	(50.5 to 53.8)

VO_2max expressed as $ml.kg^{-1}.min^{-1}$.

Speed and sprint ability

The requirement to move quickly to reposition themselves in attack and defence is essential for rugby league players.[98] Professional rugby league studies have identified that forwards rarely sprint further than 10-m and all players rarely sprint distances greater than 40-m in a single bout of intense activity.[70] Although there were no significant differences between forwards and backs for 10-m speed, forwards were consistently slower over 40-m than backs.[74] This was similar for junior sub-elite players where there were no significant differences for 10-, 20- and 40-m sprint speeds[74, 75, 98] but, like other studies, forwards were consistently slower than backs.[98]

Amateur rugby league players[91] were predictably slower in sprint speeds than semi-professional[37] and professional[188] levels of participation. Female players[88] recorded even lower sprint speeds. Backs were predictably faster than forwards at all participation levels (see Table 13).

Given that repeat-sprint ability is important in rugby league it is surprising that relatively few studies have investigated the repeated-sprint ability of rugby league players. Players were often required to sprint from the defensive line, make a tackle, chase from marker defence, and then recover to enable a repeat of these activities. The repeated sprint ability test is specifically designed to test the athlete's ability to perform in short bursts of high intensity exercise over a series of multiple efforts.[37, 188] Of the two studies[37, 188] published on repeat-sprint ability, one[37] used a 8 x 40-m repeat sprint test while the other study[188] used a 6 x 40-m repeat sprint test. There were no significant differences between player positions in professional rugby league players with the 8 x 40-m sprints test[37] but when compared with the 6 x 40-m sprint test there were significant differences amongst the different playing positions.[248] Props had the highest speed decrement (7.1%) followed by outside backs (6.2%), back-rowers (6.2%).[179] Halves and hookers recorded the lowest speed decrement at 5.1%.[216]

Although forwards recorded a slower total time to complete the repeat-sprint ability test than backs (35.02 vs. 33.65 s) they recorded a lower speed decrement than backs (5.8% vs. 6.4%).[37, 188] A limitation to conducting this test is that repeated sprint efforts in rugby league can vary in distance and recovery duration.[188] Meir et al.'s [180] study on time-motion activities of professional rugby league players identified that for every four seconds of high-intensity activity, approximately 30-80 seconds of low-intensity followed. However, further research is required to provide information on the repeated demand of rugby league at all levels of participation.[188]

Table 13: Sprint speed of forwards and backs by participation level.

Level	Position	Sprint distance							
		10-M	95% CI	20-M	95% CI	30-M	95% CI	40-M	95% CI
Professional[183]	Forward	-	-	-	-	-	-	5.27	-
	Back	-	-	-	-	-	-	5.08	-
Professional[179]	Forward	-	-	-	-	-	-	5.04	-
	Back	-	-	-	-	-	-	4.88	-
Professional[37]	Forward	1.88	-	3.18	-	4.39	-	5.57	-
	Back	1.79	-	3.07	-	4.14	-	5.28	-
Semi-professional 1st grade[74]	Forward	2.19	-	3.56	-	4.94	-	6.12	-
	Back	2.09	-	3.38	-	4.68	-	5.86	-
Semi-professional 2nd grade[74]	Forward	2.20	-	3.56	-	4.80	-	6.12	-
	Back	2.18	-	3.52	-	4.80	-	6.02	-
Elite[98]	Forward	1.88	(1.85 to 1.91)	-	-	-	-	5.64	(5.53 to 5.75)
	Back	1.82	(1.79 to 1.85)	-	-	-	-	5.45	(5.38 to 5.52)
Sub-elite[98]	Forward	2.19	(2.14 to 2.24)	-	-	-	-	6.25	(6.10 to 6.40)
	Back	2.12	(2.06 to 2.18)	-	-	-	-	5.98	(5.88 to 6.08)
Sub-elite 1st grade[75]	Forward	2.05	(1.97 to 2.13)	3.38	(3.28 to 3.48)	-	-	5.86	(5.76 to 5.96)
	Back	1.98	(1.93 to 2.03)	3.28	(3.21 to 3.35)	-	-	5.69	(5.58 to 5.80)
Sub-Elite 2nd grade[75]	Forward	2.14	(2.09 to 2.19)	3.50	(3.43 to 3.57)	-	-	6.09	(5.94 to 6.24)
	Back	2.08	(1.97 to 2.19)	3.34	(3.22 to 3.46)	-	-	5.81	(5.64 to 5.98)
Sub-elite U19[75]	Forward	2.19	(2.10 to 2.28)	3.57	(3.46 to 3.68)	-	-	6.20	(6.01 to 6.39)
	Back	2.19	(2.09 to 2.29)	3.53	(3.41 to 3.65)	-	-	6.01	(5.85 to 6.17)
Sub-elite U16[75]	Forward	2.22	(2.15 to 2.29)	3.61	(3.51 to 3.71)	-	-	6.17	(6.00 to 6.34)
	Back	2.17	(2.10 to 2.24)	3.55	(3.46 to 3.64)	-	-	6.00	(5.87 to 6.13)
Sub-elite U15[75]	Forward	2.25	(2.20 to 2.30)	3.72	(3.61 to 3.83)	-	-	6.58	(6.32 to 6.84)
	Back	2.21	(2.13 to 2.29)	3.62	(3.53 to 3.71)	-	-	6.26	(6.14 to 6.38)
Sub-elite U14[75]	Forward	2.44	(2.34 to 2.54)	3.99	(3.79 to 4.19)	-	-	7.00	(6.40 to 7.60)
	Back	2.24	(2.15 to 2.33)	3.70	(3.51 to 3.89)	-	-	6.47	(6.08 to 6.86)
Sub-elite U13[75]	Forward	2.60	(2.53 to 2.67)	4.24	(4.14 to 4.34)	-	-	7.50	(7.29 to 7.71)
	Back	2.46	(2.38 to 2.54)	4.04	(3.92 to 4.16)	-	-	7.11	(6.87 to 7.35)
Elite females[91]	Forward	2.04	-	3.60	-	-	-	6.59	-
	Back	1.96	-	3.44	-	-	-	6.33	-
Amateur[70]	Forward	2.62	(2.57 to 2.67)	-	-	-	-	6.79	(6.69 to 6.89)
	Back	2.53	(2.43 to 2.63)	-	-	-	-	6.45	(6.35 to 6.55)

Data reported as means. CI Confidence Interval.

Agility

Described as "a rapid whole body movement with change of velocity or direction in response to a stimulus",[226] agility is an essential component for rugby league. Players are required to rapidly accelerate, decelerate and change direction.[180] There are several agility tests[103] such as the Illinois agility (see Table 14), 'L' agility (see Table 15), 505 test (see Table 16), Modified 505 test, glycolytic agility (see Table 17) and the reactive agility test[103] and other 'novel'[19] tests. Inter-study comparisons were difficult to undertake because of the different tests utilised, and a further limitation of the current studies is that none of the tests assess perceptual components of agility,[103] a key component of rugby league.

Table 14: Illinois agility published results by participation level.

	Forwards		Backs		All Players	
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**
First grade[74]	17.2 ±1.0[a]	-	16.6 ±0.7[a]	-	16.9 ±0.9[a]	-
First grade[75]	17.2[b]	(16.6 to 17.8)	17.4[b]	(16.7 to 18.1)	-	-
Second grade[74]	17.2 ±1.2[a]	-	17.5 ±1.4[a]	-	17.4 ±1.3[a]	-
Second grade[75]	18.1[b]	(17.6 to 18.6)	17.7[b]	(17.3 to 18.1)	-	-
Under 19[75]	18.3[b]	(17.5 to 19.1)	17.9[b]	(17.2 to 18.6)	-	-
Under 16[75]	19.4[b]	(18.5 to 20.3)	19.1[b]	(18.4 to 19.8)	-	-
Under 15[75]	19.5[b]	(18.5 to 20.5)	19.5[b]	(18.9 to 20.1)	-	-
Under 14[75]	21.1[b]	(19.4 to 22.8)	20.3[b]	(19.4 to 21.2)	-	-
Under 13[75]	22.0[b]	(21.5 to 22.5)	21.5[b]	(20.9 to 22.1)	-	-

All data reported in seconds (s). (**a**)= Data reported as mean ±SD; (**b**)= Data reported as mean (95% CI). CI = Confidence Interval.

Table 15: ‘L’ agility test published results by participation level.

	Professional[179]		Sub-elite[88]		Junior[83]		1st grade[103]		2nd grade[103]	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Total[a]	-	-	-	-	-	-	6.36	±0.53	6.49	±0.40
Forwards[a]	5.46	±0.21	6.04[a]	±0.54[a]	5.99[a]	±0.31[a]	-	-	-	-
Backs[b]	5.37	±0.22	5.98[a]	±0.52[a]	5.90[a]	±0.12[a]	-	-	-	-
Prop[b]	-	-	6.36	±0.48	6.37	(6.21 to 6.52)	-	-	-	-
Hooker[b]	-	-	5.83	±0.60	5.86	(5.61 to 6.11)	-	-	-	-
Second row[b]	-	-	6.11	±0.60	6.10	(5.91 to 6.30)	-	-	-	-
Lock[b]	-	-	5.84	±0.47	5.64	(5.35 to 5.94)	-	-	-	-
Half-back[b]	-	-	5.93	±0.47	6.01	(5.79 to 6.24)	-	-	-	-
Five-eighth[b]	-	-	6.16	±0.64	5.71	(5.34 to 6.08)	-	-	-	-
Centre[b]	-	-	5.94	±0.44	5.89	(5.68 to 6.09)	-	-	-	-
Wing[b]	-	-	5.96	±0.54	5.98	(5.85 to 6.12)	-	-	-	-
Fullback[b]			5.89	±0.50	5.90	(5.72 to 6.08)	-	-	-	-

All data reported in seconds (s) (**a**)=Data reported as mean ±SD; (**b**)=Data reported as mean (95% CI).

CI = Confidence Interval. a= calculated mean ±SD of ‘L’ agility scores.

Table 16: 505 agility test published results by participation level.

	Total	
	Mean	**SD or 95% CI**
Junior elite[102]	2.30[a]	±0.13
Junior sub-elite[102]	2.38[a]	±0.16
Elite Under 17[98]	2.36[b]	(2.28 to 2.44)
Elite Under 16[98]	2.40[b]	(2.35 to 2.45)
Elite Under 15[98]	2.45[b]	(2.41 to 2.49)
Sub-elite Under 17[98]	2.68[b]	(2.60 to 2.76)
Sub-elite Under 16[98]	2.85[b]	(2.80 to 2.90)
Sub-elite Under 15[98]	2.89[b]	(2.85 to 2.93)
Sub-elite forward[98]	2.77[b]	(2.72 to 2.82)
Sub-elite backs[98]	2.76[b]	(2.61 to 2.91)
Elite forwards[98]	2.45[b]	(2.41 to 2.49)
Elite backs[98]	2.38[b]	(2.34 to 2.42)
First grade[103]	2.34[a]	±0.20
Second grade[103]	2.39[a]	±0.15

All data reported in seconds (s). (**a**)=Data reported as mean ±SD; (**b**)=Data reported as mean (95% CI). CI = Confidence Interval.

Table 17: Glycolitic agility test published results by participation level.

		Mean	SD or Range
Professional[188]	Backs[a1]	45.3	±3.33
	Halves[a2]	45.89	±3.03
	Back row[a3]	46.55	±2.73
	Props	46.71	±2.89
	Hookers	46.20	±2.84
Professional[186]	Backs	44.92	(40.20 to 51.90)
	Forwards	46.67	(41.83 to 52.32)
	Under 21	46.01	(40.27 to 51.90)
	Reserve grade	46.00	(40.20 to 52.32)
	First grade	45.09	(40.20 to 52.30)
Elite women[91]	Forwards	53.1	±2.6
	Backs	51.6	±3.7
	Hit-up forwards	53.5	±2.9
	Adjustables	51.9	±1.7
	Outside backs	51.2	±5.1

All data reported in seconds (s) a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row.

More recently other agility tests more specific to rugby league have appeared in the literature. A 'novel' test used on professional and semi-professional players required a 40-m distance to be covered incorporating two 45º and a single 135º turns to be made.[19] It was thought that this would mimic some aspects of movement when players were defending[19] although no results have been presented. The Reactive Agility Test (RAT) initially utilised in netball,[60] has been compared with change of direction speed and sprint speed[103, 226] and with other agility tests[103] and appears relevant to rugby league. Superior movement speed (2.48 ±0.17 s vs. 2.60 ±0.16 s), decision times (55.3 ±43.6 ms vs. 78.2 ±40.4 ms) and response accuracy (89.3 ±13.9% vs. 84.0 ±17.3%) have been reported in first grade compared with second grade players.[103] There is practical utility of the RAT for assessment of perceptual components of agility in players.[103]

Muscular strength and power

For rugby league players to be successful, one of the key characteristics is their capacity to generate high levels of muscular force[183] to effectively tackle, lift, pull, and push opponents during match activities. Muscular strength and power are also essential requirements to enable leg drive to occur in the tackle.[104]

There were many studies that have examined strength characteristics of rugby league players.[11, 12, 14, 183, 188] For example, Meir[179] reported significant differences between forwards and backs for bench press (119 vs. 113 kg) and one-repetition maximum (1-RM) squat (188 vs. 168 kg).

O'Connor[188] confirmed these findings by reporting significantly greater three-repetition maximum (3-RM) squat, power-clean and bench-press in props (149.3 kg, 92.5 kg, 123.4 kg) and back rowers (143.5 kg, 86.8 kg, 112.4 kg) when compared with hookers (130.0 kg, 76.0 kg, 99.7 kg), halves (131.0 kg, 78.8 kg, 100.1 kg) and outside backs (135.6 kg, 81.4 kg, 106.0 kg) respectively.

In other studies[11, 14, 15, 188] professional rugby league players had a 3-RM squat of 157.9 ±18.8 kg, a 3-RM bench press of 124.0 ±13.0 kg and a 3-RM power clean of 102.2 ±13.4 kg. Professional rugby league players, when compared with college aged,[11] and junior high school aged rugby league players,[14] had significantly greater maximal strength and power. This was attributed, in part, to the neural adaptations that have occurred with long-term periodised strength and power training that professional players undertake in their training regime.[98]

Some studies that have examined strength in rugby league players have used the vertical jump test to assess leg muscular power.[98] There is a progressive improvement in the muscular power as the participation level increased (see Table 18), and one study[102] identified that players that were selected to start in the first match of the season had a greater mean vertical jump score than the non-starters for both junior elite (52.6 ±7.8 vs. 49.4 ±7.5 cm) and junior sub-elite (46.8 ±7.3 vs. 45.9 ±7.7 cm) players.

Table 18: Vertical jump scores of forwards and backs by participation level.

	Forwards		**Backs**	
Study	**VJ (cms)**	**95% CI**	**VJ (cms)**	**95% CI**
Semi-professional 1st grade[74]	40.7	-	46.7	-
Semi-professional 2nd grade[74]	43.7	-	40.2	-
Elite[98]	51.1	(48.9 to 53.3)	54.1	(51.5 to 56.7)
Sub-elite[98]	38.2	(35.2 to 41.2)	40.6	(38.0 to 43.2)
Sub-elite 1st grade[75]	48.7	(42.1 to 55.3)	50.9	(47.5 to 54.3)
Sub-elite 2nd grade[75]	41.0	(37.8 to 44.2)	42.9	(39.3 to 46.5)
Sub-elite Under 19[75]	37.9	(33.1 to 42.7)	40.0	(35.1 to 44.9)
Sub-elite Under 16[75]	38.0	(34.4 to 41.6)	41.2	(37.7 to 44.7)
Sub-elite Under 15[75]	34.7	(29.2 to 40.2)	37.1	(34.3 to 39.9)
Sub-elite Under 14[75]	33.1	(26.8 to 39.4)	38.5	(32.7 to 44.3)
Sub-elite Under 13[75]	28.2	(21.7 to 34.7)	30.8	(38.2 to 33.4)
Elite females[91]	35.1	-	35.7	-
Amateur[70]	37.1	(33.7 to 40.5)	39.3	(36.1 to 42.5)

Data reported as mean scores. CI = Confidence Interval. VJ = Vertical Jump.

Comparison of muscular strength positional groups using the vertical jump is limited as different authors have used either different positional group combinations[70, 74, 83, 88, 102] with either standard deviations[88] or 95% confidence intervals[83] for player positions (see Table 19) and either standard deviations[88] or 95% confidence intervals[83] (see Table 20) or a mean score for all players[70, 74, 102] (see Table 21). Different participation levels have varying results with no playing group or position recording greater vertical jump scores throughout all participation levels.

Table 19: Vertical jump scores of rugby league positional by participation level.

Participation level	Positional group	Mean (cms)	±SD	95% CI
Professional[188]	Backs[a1]	45.3	3.3	-
	Halves[a2]	45.9	3.0	-
	Back row[a3]	46.6	2.7	-
	Props	47.6	2.9	-
	Hookers	46.2	2.8	-
Sub-elite[88]	Props	43.4	9.0	-
	Hooker/Halves[b1]	47.7	10.3	-
	Back row[b2]	46.0	11.1	-
	Outside backs[b3]	48.3	10.6	-
Elite Female[91]	Hit up forwards[c1]	34.3	8.6	-
	Adjustables[c2]	35.6	5.5	-
	Outside backs[c3]	37.0	7.0	-
Junior[83]	Props	44.0	-	(41.6 to 46.4)
	Hooker/Halves[b1]	49.0	-	(46.2 to 51.7)
	Back row[b2]	48.2	-	(45.1 to 51.3)
	Outside backs[b3]	47.1	-	(45.1 to 49.1)

a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row;
b1= Hooker, halfback, five-eight/stand-off; b2= second row, lock; b3= centre, wing, fullback;
c1= second row, prop; c2= hooker, half-back, five-eight/stand-off, lock; c3= centre, wing, fullback.

Table 20: Vertical jump height scores of rugby league specific positions by participation level.

	Sub-Elite[88]		Junior[83]	
Playing position	**cm**	**±SD**	**cm**	**(95% CI)**
Prop	43.4	9.0	44.0	(41.6 to 46.4)
Hooker	50.9	10.5	47.9	(44.3 to 52.0)
Second row	45.7	10.5	49.0	(45.5 to 52.6)
Lock	46.6	12.4	45.2	(38.6 to 51.8)
Halfback	48.4	9.0	50.4	(45.8 to 54.0)
Five-eight	41.0	7.7	48.5	(43.0 to 54.0)
Centre	50.0	8.8	50.4	(46.9 to 53.9)
Wing	46.5	12.0	45.4	(42.6 to 48.2)
Fullback	47.4	11.9	42.8	(38.2 to 47.3)

Table 21: Vertical jump height scores of rugby league players by participation level.

	cm	±SD
Junior Elite[102]	51.6	7.7
Junior Sub-Elite[102]	46.9	6.8
Amateur[70]	38.1	7.1
Semi-Professional[74]	42.5	8.8

Changes over a season

All but a few[82, 207] studies examining the physiologic and anthropometric characteristics of rugby league players have utilised cross sectional analysis. The studies that undertook a longitudinal review of the physiologic and anthropometric changes of rugby league players have highlighted the changes that occur as the season progresses for amateur,[82] semi-professional[45] and junior elite[86] rugby league. The early part of the season is where the greatest improvements occur[86] but performance reportedly deteriorates as the season progresses (see Table 22). Early season improvements were attributed to high training loads that players underwent in preparation for the competition season whereas the deterioration of the players' fitness improvements was attributed to reductions in training loads throughout the season.[86]

Table 22: Body mass, sum of skinfolds, muscular power, speed, agility and estimated maximal aerobic power of rugby league players during a competitive season by participation level.

		Off-Season		Pre-Season		Mid-Season		End-Season	
		mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Body Mass (kg)	Amateur[82]	84.2	(78.3 to 90.0)	82.0	(76.4 to 87.5)	84.5	(79.0 to 90.1)	86.2	(80.7 to 91.7)
	Junior[86]	83.3	(72.2 to 94.3)	79.9	(74.1 to 85.8)	78.2	(72.8 to 83.7)	79.0	(73.7 to 84.4)
Sum of Skinfolds (mm)	Amateur[82a]	90.7	(78.1 to 103.2)	84.7	(73.2 to 96.2)	84.3	(71.2 to 97.4)	93.4	(82.1 to 104.7)
	Junior[86b]	93.9	(71.4 to 116.4)	85.2	(72.8 to 97.7)	83.6	(72.1 to 95.0)	84.4	(73.4 to 95.4)
10-m Sprint (s)	Amateur[82]	1.83	(1.78 to 1.89)	1.85	(1.81 to 1.89)	1.80	(1.77 to 1.83)	1.80	(1.77 to 1.83)
	Junior[86]	1.82	(1.75 to 1.90)	1.85	(1.81 to 1.88)	1.82	(1.78 to 1.86)	1.79	(1.76 to 1.82)
20-m Sprint (s)	Amateur[82]	3.15	(3.05 to 3.24)	3.12	(3.06 to 3.19)	3.13	(3.08 to 3.18)	3.10	(3.06 to 3.14)
	Junior[86]	3.12	(2.99 to 3.25)	3.11	(3.05 to 3.17)	3.13	(3.06 to 3.19)	3.09	(3.05 to 3.13)
40-m Sprint (s)	Amateur[82]	5.61	(5.43 to 5.79)	5.61	(5.48 to 5.74)	5.62	(5.52 to 5.72)	5.53	(5.46 to 5.61)
	Junior[86]	5.56	(5.30 to 5.82)	5.58	(5.76 to 5.92)	5.64	(5.51 to 5.77)	5.52	(5.45 to 5.58)
Agility (s)	Amateur[82]	6.03	(5.88 to 6.18)	5.92	(4.82 to 5.02)	5.95	(5.74 to 6.16)	5.94	(5.82 to 6.06)
	Junior[86]	5.93	(5.71 to 6.14)	5.84	(5.76 to 5.92)	5.55	(5.28 to 5.81)	5.82	(5.70 to 5.94)
Vertical Jump (cm)	Amateur[82]	55.4	(52.1 to 58.8)	58.6	(56.0 to 61.2)	55.7	(53.2 to 58.1)	55.5	(53.6 to 57.4)
	Junior[86]	54.8	(50.4 to 59.2)	58.2	(56.0 to 60.3)	56.8	(54.2 to 59.5)	57.8	(55.7 to 60.0)
VO_2max (ml.kg-1.min-1)	Amateur[82]	42.0	(38.8 to 45.1)	48.5	(46.1 to 50.9)	51.3	(49.6 to 52.9)	49.6	(47.5 to 51.7)
	Junior[86]	43.7	(39.9 to 47.5)	50.6	(48.5 to 52.8)	53.5	(51.7 to 55.3)	52.1	(50.5 to 53.8)

Data reported as means (95% confidence interval). VO_2max = estimated maximal aerobic power; a= sum of 7 skinfolds (biceps, triceps, subscapular, supraspinale, abdomen, thigh, and calf on the right side); b= sum of four skinfolds (biceps, triceps, subscapular, and suprailiac).

Conclusion

This review summarised the available published data of anthropometric and physiologic characteristics of rugby league players. Physiological aspects of rugby league players can change during matches and over the participation season in regards to muscular power, maximal aerobic capacity and skin-fold thickness. The resulting fatigue combined with the playing intensity has been suggested as a contributor to the incidence of injuries in rugby league players. More research is warranted on the physiologic aspects of amateur, junior and female players. Although there were some established data available this is typically from single teams at one level of participation and predominately for male players.

CHAPTER 4: RUGBY LEAGUE INJURIES IN NEW ZEALAND: A REVIEW OF EIGHT YEARS OF ACCIDENT COMPENSATION CORPORATION INJURY ENTITLEMENT CLAIMS AND COSTS

This chapter comprises the following paper accepted by the British Journal of Sports Medicine

Reference

King, DA., Hume, P., Milburn, P. & Gianotti, S. Rugby league injuries in New Zealand: a review of eight years of accident compensation corporation injury entitlement claims and costs. *British Journal of Sports Medicine.* 2009. **43**(8):595-602

Author contributions

King, D. 70%; Hume, P. 15%; Milburn, P. 10%; Gianotti, S. 5%

Overview

This study provides an overview of the epidemiology of rugby league injuries and associated costs in New Zealand requiring medical treatment. New Zealand national Accident Compensation Corporation injury data for the period 1999 to 2007 were searched for rugby league injury cases. Data were analysed by demographics, body region, nature/severity of injury, and medical procedure and costs. A total of 5,941 injury entitlement claims were recorded over the study period with a significant decrease observed in the injury rate between the 1999-00 and 2002-03 reporting years. The total cost of the injuries for the study period was $42,822,048 [£15,916,072]. The mean ±SD number of injury entitlement claims per year was 743 ±271 and yearly cost was $5,352,760 [£1,989,880] (±$2,485,535 [£923,994]). The knee was the most commonly reported injury site (225 per 1000 entitlement claims; $8,750,147 [£3,252,020]) and soft tissue injuries were the most common injury types (474 per 1000 entitlement claims; $17,324,214 [£6,438,599]). Accounting for only 2% of total injury entitlement claims, concussion/brain injuries accounted for 6% of injury entitlement costs and had the highest mean cost per claim ($25,347 [£9,420]). The upper and lower arm recorded the highest mean injury site claim cost of $43,096 [£16,016] per claim. The 25-29 age group recorded 28% of total injury entitlement claims and 30% of total injury entitlement costs which was slightly more than the 20-24 age group (27% claims; 25% costs). Nearly 15% of total MSC injury entitlement claims and 20% of total costs were recorded from participants 35 years or older. This study identified that the knee was the most common injury site and soft tissue injuries were the most common injury type requiring medical treatment, which is consistent with other international studies on rugby league epidemiology. This study also highlighted that both the rate of injury and the average age of injured rugby league players increased over time. The high cost of concussion/brain injuries is a cause for concern as it reflects the severity of the injuries. Injury prevention programmes for rugby league should focus on reducing the risk of concussion/brain injury and knee and soft tissue injury, and should target participants in the 20-30 year age range. More longitudinal epidemiological studies with specific details on injury mechanisms and participation data are warranted to further identify the injury circumstances surrounding participation in rugby league activities.

Introduction

Rugby league is an intermittent contact sport that is played internationally at junior,[92] amateur,[150, 152] semi-professional[77] and professional[119, 137] levels of participation. By nature, it is an intermittent collision sport that requires the participants to compete with a combination of muscular strength, stamina, endurance, speed, acceleration, agility, flexibility and aerobic endurance.[179, 180] As such there is a risk of musculoskeletal injury occurring from both the match and training environments[77, 92, 119, 137, 150, 152] due to the number of physical collisions and tackles that occur. Injury may result in hospitalization, inability to participate in training and match activities and inability to participate in work related activities. This may also result in loss of income to the injured player, financial costs for medical related care and job limitations owing to the severity and type of the injuries that have occurred.

Several published studies on the incidence of injuries in rugby league[77, 92, 114, 119, 137, 150, 152] have identified changes in the injury incidence as a result of changes in playing season,[119, 134, 137] rule changes[198] and different participation levels.[77, 92, 114, 119, 137, 150, 152] Professional participation has a 1.3 to 2.2 fold higher injury rate than amateur participation,[78] and semi-professional participants have the highest injury incidence (825 per 1000 player position game hours).[77, 78]

Despite an increasing number of international studies on rugby league injuries there is a paucity of studies describing injuries in New Zealand rugby league players. There is limited longitudinal rugby league injury surveillance data and a paucity of studies on the financial costs of injuries that have occurred as a result of participating in rugby league activities. Published studies[72, 182] that have provided an insight into some of the associated costs of rugby league injuries have looked at a limited number of participants via surveys. These studies reported a median direct (£28 [$A76])[72] and indirect (£77 [$A207])[72] cost per playing injury as well as long-term job limitations, medical costs and loss of income as a result of injuries that were sustained from participating in rugby league activities.[182] No studies to date have undertaken an epidemiological review of the costs of an injury from rugby league participation.

With this in mind the aim of this study was to provide an epidemiological overview of rugby league injuries and associated costs in one country (New Zealand) over eight years. New Zealand's national taxpayer funded no-fault injury compensation system administered by the Accident Compensation Corporation (ACC) means that New Zealand is uniquely positioned to provide detailed descriptive epidemiological data including costs associated with treatment. Using these data, comparisons of the rate, site, type, cost and location of rugby league injuries over 1999 to 2007 were conducted.

Methods

People who have a personal injury make an open access claim to ACC at the time of seeking medical treatment from over 30000 registered health professionals throughout New Zealand. When making a claim, information about the injury is collected using a standard ACC 45 injury reporting form to ensure levels of consistency for data recording and analyses. The injured person (unless impaired) completes information about the activity surrounding the injury (e.g., location, activity prior, cause, narrative) along with their personal details (e.g., age, gender, ethnicity, contact details). The registered health professional completes the form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and details are entered into a central database. ACC covers compensation for the injury (sporting or other) including medical treatment, income replacement, social and vocational rehabilitation and ancillary services (transportation and accommodation) as part of the rehabilitation. [111]

ACC makes no disincentive for making claims nor are people risk-rated or penalised for the amount of claims they make.[111] Personal injury coverage is guaranteed by ACC but this is offset by the restriction to sue for personal injury except in rare circumstances for exemplary damages.[111] ACC categorises the rugby league claims made as minor or moderate to serious claims (MSC). Throughout the study period there were 42754 rugby league claims costing ACC $NZD 48,704,704 [£18,099,470]. MSC represented 14% (5943) of the number of total rugby league claims but 88% ($NZD 42,822,048 [£15,916,048]) of the costs. For this study we focused on MSC rather than minor rugby league claims as defined by the ACC for its sports cost outcome model,[111] that occurred between 1st July 1999 and the 30th June 2007 as a result of participating in rugby league activities. A potential limitation to the ACC data are the way the data are retrieved to protect client confidentiality by limiting the access to low level results under four injury entitlement claims. Therefore any data less than or equal to three injury claims have been rounded to represent three claims only.

As there were no reliable rugby league participation data collected by New Zealand Rugby League, New Zealand population data were obtained from official government data. This data set provides estimates of resident populations between each five year census.[1] The population of New Zealand over the study period was approximately 4.1 million people based on the 2006 census.[1]

ACC data were analysed by various categories: (1) Injury site; (2) Injury type; (3) Age; (4) Region/District (see Table 23).

Ethical consent

Ethical consent for the research was obtained from the Auckland University of Technology Ethics Committee. Informed consent from the injured participants was not obtained as data were collected from the ACC data base without individual player identification or follow-up.

Table 23: Data categories analysed.

Region		Injury site		Injury type	Age
Area	**District**	**Group**	**Sub-group**		**in years**
North Island		**Head/Neck**		Soft tissue injury	5 - 9
	Northland		Head (except face)	Corrosive injuries	10 - 14
	Auckland		Face	Dental injuries	15 - 19
	Waikato		Eye	Fracture / Dislocation	20 - 24
	Bay of Plenty		Nose	Hernia	25 - 29
	Gisborne		Ear	Laceration, puncture, wound, sting	30 - 34
	Hawke's Bay		Neck / Back of head / vertebrae	Foreign body in orifice / eye	35 - 39
	Taranaki	**Upper Limb**		Concussion / brain injury	40 - 44
	Manawatu-Wanganui		Shoulder (including Clavicle/Shoulder blade)	Amputation	45 - 49
	Wellington		Upper and Lower Arm	Deafness	50 - 54
South Island			Elbow	Other	55 - 59
	Tasman		Hand / wrist	Unknown	60 - 64
	Nelson		Finger / Thumb		65 - 69
	Marlborough	**Lower Limb**			70 - 79
	Canterbury		Hip/Upper leg/Thigh		80 +
	West Coast		Knee		
	Otago		Lower Limb		
	Southland		Ankle		
Other			Foot		
Unknown			Toes		
		Chest / Back / Other			
			Abdomen / Pelvis		
			Chest		
			Back / Spine		
			Internal organ		
			Multiple locations		
		Unknown			

Statistical analyses

All the data collected were entered into a Microsoft Excel spreadsheet and analysed with SPSS v.16.0. (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of injuries per 1000 injury entitlement claims.[135] Data are reported as means and standard deviations and with 95% confidence intervals (CI) where appropriate.[240] The injury rates and patterns were compared between reporting years using a one sample chi-squared (χ^2) test. Significant p values reported in the text are less than 0.001 if they are not specifically stated. Injury rate for two selected periods (2002-2003 and 2006-2007) were compared in more detail. These years were chosen as they reflected the lowest and highest injury claim rates for rugby league over the eight year period. Injury incidence was not calculated for the study as rugby league participation rates were not available as part of the data analysis. All costs are reported in New Zealand Dollars ($) and United Kingdom Pounds (£) unless otherwise indicated.

Results

Over the July 1999 to June 2007 period there were 5943 moderate to serious injury entitlement claims recorded for rugby league injury. Initially the injury entitlement claims and costs decreased (claims: 8%, ±5%; costs: 2%, ±4%) over the 1999-00 to the 2001-02 reported periods. But from the 2002-03 to the 2006-07 reporting periods, the injury entitlement claims increased per reporting year (claims: mean 26%, ±20%; costs: mean 43%, ±10%). There was a significant decrease in the injury rate between the 1999-00 and 2002-03 reporting years (see Table 24) from 105 to 81 per 1000 injury entitlement claims, but a significant increase in the injury rate to 195 per 1000 injury entitlement claims in 2006-07 compared with 2002-03. The injury claims and costs varied by reporting year from 539 MSC injury entitlement claims $3,616,427 [£1,341,812] in 2000-2001 to 1162 MSC injury entitlement claims $10,542,550 [£3,911,126] in 2006-07. The mean number of yearly injury entitlement claims over the study period was 743 ±271 and the mean yearly cost was $5,352,760, ±$2,485,536 [£1,985,045, ±£921,748)]. The mean cost per claim for the study period was $7,100, ±$945 [£2,631, ±£350]. The mean cost of the non MSC injury entitlement claims was $161, ±34 [£60, ±£13].

Table 24: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences by year. Total injury costs, percentage of total costs and mean cost per claim by reporting year.

	Total Injury Claims			Total Injury Costs			Difference from previous year for total injury claims		Difference from 99-00 for total injury claims		Difference from 02-03 for total injury claims	
Years	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean$**	**χ^2 (df=1), p value**		**χ^2 (df=1), p value**		**χ^2 (df=1), p value**	
99-00	627	105.5 (97.6 to 114.1)	10.6	3,811	8.9	6,078	-		-		18	<0.001
00-01	539	90.7 (83.4 to 98.7)	9.1	3,617	8.4	6,710	6	0.010	6	0.010	2	0.092
01-02	503	84.6 (77.6 to 92.4)	8.5	3,683	8.6	7,322	1	0.265	13	<0.001	0.3	0.567
02-03	485	81.6 (74.7 to 89.2)	8.2	3,640	8.5	7,505	0.3	0.567	18	<0.001	-	
03-04	619	104.2 (96.3 to 112.7)	10.4	4,366	10.2	7,054	16	<0.001	0.1	0.821	16	<0.001
04-05	945	159.0 (149.2 to 169.5)	15.9	5,806	13.6	6,144	67	<0.001	64	<0.001	147	<0.001
05-06	1063	178.9 (168.4 to 189.9)	17.9	7,357	17.2	6,921	6	0.009	112	<0.001	215	<0.001
06-07	1162	195.5 (184.6 to 207.1)	19.6	10,543	24.6	9,073	4	0.036	159	<0.001	272	<0.001

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury entitlement claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Total injury entitlement claims and costs by district

More injury entitlement claims were recorded in the North Island (761 per 1000 injury entitlement claims; 76%) than the South Island (215 per 1000 injury entitlement claims, 22%) (χ^2=1904, df=1) (see Table 25). Over three quarters of the costs were for North Island players (North: $32,432,546 [£12,017,242]; 78%; South: $9,330,145 [£3,457,102] and 22%). Despite this, the mean cost per injury entitlement claim was higher in the South than the North Island ($7,278 [£2,701] vs. $7,164 [£2,658]). In the North Island, Auckland recorded more claims (386 per 1000 injury entitlement claims; 39%) and costs ($16,197,746 [£6,005,941]; 38%) than other North Island districts (χ^2=7298, df=8) while Canterbury recorded more claims (152 per 1000 injury entitlement claims; 15%) and costs ($9,699,320 [£3,953,815]; 15%) than other South Island districts (χ^2=3047, df=6). Otago recorded 2% of claims (22 per 1000 entitlement claims) and 4% of total costs ($1,514,433 [£561,114]) but had the highest mean cost per claim for all districts ($11,387 [£4,218]).

Total injury entitlement claims and costs by injury site

There were significant differences in the total number of injury entitlement claims for injuries to the head and neck (χ^2=59, df=5), upper limbs (χ^2=304, df=4), lower limbs (χ^2=245, df=5) and chest and back (χ^2=66, df=4). The knee was the most commonly recorded injury site followed by the shoulder; ankle and hand/wrist (see Table 26). The lower limb recorded 42% of the injury entitlement claims and 32% of the total injury claim costs ($13,490,695 [£4,999,486]). The mean cost of a lower limb injury entitlement claim ($5,358 [£1,996]) was lower than the mean cost of an upper limb injury entitlement claim ($5,361 [£1,988]). Although the upper and lower arm recorded 6% of total injury entitlement claims and 5% of total injury entitlement costs, the upper and lower arm recorded the highest mean injury entitlement claim cost of $43,097 [£15,979] per claim. This was more than the mean injury entitlement claim cost for the head (except face) ($28,725 [£10,648]), neck, back of head ($23,944 [£8,876]) and back/spine ($23,461 [£8,699]). The knee recorded the most total injury entitlement claims (23%) accounting for 20% of total injury entitlement costs ($8,750,147 [£3,244,247]) with a mean claim cost of $6,540 [£2,424]. This was less than the mean cost of the shoulder injury entitlement claim ($6,802 [£2,521]).

Table 25: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by district 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by district 1999 to 2007.

	Total Injury Claims			Total Injury Costs			Difference from Auckland for total injury claims	
North Island	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=1), p value**	
Total	**4527**	**761.7 (739.9 to 784.3)**	**76.2**	**32,433**	**75.7**	**7,164**	**-**	
Northland	242	40.7 (35.9 to 46.2)	4.1	1,040	2.4	4,297	1664	<0.001
Auckland	2,298	386.7 (371.2 to 402.8)	38.7	16198	37.8	7,049	-	
Waikato	550	92.5 (85.1 to 100.6)	9.3	4,263	10	7,750	1072	<0.001
Bay of Plenty	351	59.1 (53.2 to 65.6)	5.9	2,472	5.8	7,044	1431	<0.001
Gisborne	80	13.5 (10.8 to 16.8)	1.3	412	1.0	5,146	2068	<0.001
Hawkes' Bay	124	20.9 (17.5 to 24.9)	2.1	623	1.5	5,022	1951	<0.001
Taranaki	198	33.3 (29.0 to 38.3)	3.3	1,342	3.1	6,779	1766	<0.001
Manawatu-Wanganui	245	41.2 (36.4 to 46.7)	4.1	2,241	5.2	9,147	1657	<0.001
Wellington	439	73.9 (67.3 to 81.1)	7.4	3,842	9.0	8,752	1262	<0.001

	Total Injury Claims			Total Injury Costs			Difference from Canterbury for total injury claims	
South Island	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=1), p value**	
Total	**1282**	**215.7 (204.2 to 227.9)**	**21.6**	**9,330**	**21.8**	**7,278**	**-**	
Tasman	9	1.5 (0.8 to 2.9)	0.2	13	0.0	1,475	879	<0.001
Nelson	34	5.7 (4.1 to 8.0)	0.6	114	0.3	3,348	808	<0.001
Marlborough	28	4.7 (3.3 to 6.8)	0.5	119	0.3	4,261	825	<0.001
Canterbury	906	152.4 (142.8 to 162.7)	15.2	9,699	15.6	10,706	-	
West Coast	124	20.9 (17.5 to 24.9)	2.1	653	1.5	5,269	593	<0.001
Otago	133	22.4 (18.9 to 26.5)	2.2	1,514	3.5	11,387	575	<0.001
Southland	65	10.9 (8.6 to 13.9)	1.1	308	0.7	4,738	728	<0.001

	Total Injury Claims			Total Injury Costs		
Other / Unknown	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**
Total	**131**	**22.0 (18.6 to 26.2)**	**2.2**	**968**	**2.3**	**7,390**
Other	34	5.7 (4.1 to 8.0)	0.6	303	0.7	8,917
Unknown	97	16.3 (13.4 to 19.9)	1.6	665	1.6	6,855

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury entitlement claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 26: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by injury site from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by injury site from 1999 to 2007.

Body Site	Total Injury Claims			Total Injury Costs			Difference over reporting years for total injury claims		Difference 99-00 and 06-07 for total injury claims	
	No.	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**	
Head & Neck	**549**	**92.4 (85.0 to 100.4)**	**9.2**	**9,315**	**21.8**	**16,967**	**64**	**<0.001**	**0.9**	**0.342**
Head (except face)	149	25.1 (21.4 to 29.4)	2.5	4,280	10	28,725.	15	0.025	0.6	0.431
Neck, Back of head	169	28.4 (24.5 to 33.1)	2.8	4,047	9.4	23,944	30	<0.001	0	0.938
Face	128	21.5 (18.1 to 25.6)	2.2	661	1.5	5,167	19	0.007	0.8	0.361
Eye	27	4.5 (3.1 to 6.6)	0.5	80	0.2	2,955	1	0.992	0	0.884
Ear	18	3.0 (1.9 to 4.8)	0.3	37	0.1	2,048	6	0.540	0.5	0.443
Nose	58	9.8 (7.5 to 12.6)	1.0	210	0.5	3,622	14	0.038	0.6	0.425
Upper Limb	**2334**	**392.7 (377.1 to 409.0)**	**39.3**	**12,512**	**29.2**	**5,360**	**315**	**<0.001**	**0.1**	**0.810**
Shoulder	1008	169.6 (159.5 to 180.4)	17	6,857	16	6,802	178	<0.001	3	0.075
Upper & Lower Arm	48	58.6 (52.7 to 65.0)	5.9	2,069	4.8	43,097	42	<0.001	2	0.143
Elbow	104	17.5 (14.4 to 21.2)	1.7	488	1.1	4,688	9	0.247	3	0.053
Hand/wrist	528	88.8 (81.6 to 96.8)	8.9	2,096	4.9	3,970	60	<0.001	5	0.025
Finger/Thumb	346	58.2 (52.4 to 64.7)	5.8	1,002	2.3	2,897	57	<0.001	0	0.985
Lower Limb	**2518**	**423.7 (407.5 to 440.6)**	**42.4**	**13,491**	**31.5**	**5,357**	**259**	**<0.001**	**1**	**0.189**
Hip, Upper leg, Thigh	116	19.5 (16.3 to 23.4)	2.0	496	1.2	4,279	21	0.003	0.5	0.498
Knee	1,338	225.1 (213.4 to 237.5)	22.5	8,750	20.4	6,540	148	<0.001	1	0.194
Lower Leg	339	57.0 (51.3 to 63.4)	5.7	1,492	3.5	4,401	32	<0.001	6	0.014
Ankle	633	106.5 (98.5 to 115.1)	10.7	2,560	6.0	4,045	68	<0.001	0.4	0.492
Foot	77	13.0 (10.4 to 16.2)	1.3	186	0.4	2,415	25	0.001	1	0.247
Toes	15	2.5 (1.5 to 4.2)	0.3	6	0	402	9	0.253	5	0.018
Chest, Back, Other	**386**	**65.0 (58.8 to 71.8)**	**6.5**	**4,511**	**10.5**	**11,685**	**31**	**<0.001**	**0**	**0.852**
Chest	172	28.9 (24.9 to 33.6)	2.9	251	0.6	1,457	34	<0.001	5	0.016
Back/Spine	174	29.3 (25.2 to 34.0)	2.9	4,082	9.5	23,461	13	0.067	0.7	0.397
Abdomen/Pelvis	25	4.2 (2.8 to 6.2)	0.4	151	0.4	6,049	7	0.336	5	0.021
Internal organs	12	2.0 (1.1 to 3.6)	0.2	25	0.1	2,058	12	0.101	0.5	0.463
Multiple locations	3	0.5 (0.2 to 1.6)	0.1	2	0.0	642	21	0.004	5	0.018
Unknown	**199**	**33.5 (29.1 to 38.5)**	**3.3**	**2,995**	**7**	**15,047**	**61**	**<0.001**	**3**	**0.048**

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury entitlement claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 27: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by injury type from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by injury type from 1999 to 2007.

	Total Injury Claims			Total Injury Costs			Difference over reporting years		Difference between 99-00 and 06-07	
Injury type	**No.**	**Rate** *(95% CI)*	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**	
Soft Tissue Injuries	2817	474.0 (456.8 to 491.8)	47.4	17,324	40.5	6,150	330	<0.001	0	0.875
Fracture / Dislocations	2618	440.5 (424.0 to 457.7)	44.1	16,935	39.5	6,469	304	<0.001	0.9	0.335
Other	198	33.3 (29.0 to 38.3)	3.3	3,324	7.8	16,788	50	<0.001	1	0.248
Concussion / Brain Injury	107	18.0 (14.9 to 21.8)	1.8	2,712	6.3	25,347	20	0.005	2	0.146
Lacerations / Puncture / Wounds	97	16.3 (13.4 to 19.9)	1.6	301	0.7	3,107	16	0.023	0.3	0.562
Unknown	77	13.0 (10.4 to 16.2)	1.3	1,780	4.2	23,111	9	0.191	0	0.870
Dental Injuries	26	4.4 (3.0 to 6.4)	0.4	4196	1.0	16,109	0.5	0.999	1	0.221
Deafness	12	2.0 (1.1 to 3.6)	0.2	14	0.0	1,178	12	0.101	1	0.203
Hernia	6	1.0 (0.5 to 2.2)	0.1	8	0.0	1,325	18	0.012	1	0.203
Corrosive Injuries	3	0.5 (0.2 to 1.6)	0.1	3	0.0	1,075	21	0.004	1	0.203
Foreign body in orifice / eye	3	0.5 (0.2 to 1.6)	0.1	1	0.0	411	21	0.004	1	0.203

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury entitlement claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Total injury entitlement claims and costs by injury type

Soft tissue injuries were the most common rugby league injury entitlement claims lodged while fractures/dislocations were slightly less (see Table 27). Accounting for only 2% of total injury entitlement claims, concussion/brain injuries accounted for 6% of injury entitlement costs ($2,712,139 [£1,012,763]) with the highest mean cost per claim ($25,347 [£9,487]). This was more than the mean cost of injury entitlement claims for fracture/dislocations ($6,469 [£2,422]), soft tissue injuries ($6,149 [£2,302]) and lacerations/puncture/wounds ($3,107 [£1,162]).

Table 28: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by age from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by age from 1999 to 2007.

	Total Injury Claims			Total Injury Costs			Sig. Diffs.
Age	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	
5 - 9	7	1.2 (0.6 to 2.5)	0.1	9	0.0	1,279	bcdefghijklmo
10-14	94	15.8 (12.9 to 19.4)	1.6	325	0.8	3,462	acdefghjklmno
15-19	844	142 (132.8 to 151.9)	14.2	4,480	10.5	5,308	abdefghijklmno
20-24	1624	273.3 (260.3 to 286.9)	27.3	10,591	24.7	6,522	abcfghijklmno
25-29	1645	276.8 (263.7 to 290.5)	27.7	12,693	29.6	7,716	abcfghijklmno
30-34	885	148.9 (139.4 to 159.1)	14.9	6,080	14.2	6,870	abcdeghijklmno
35-39	545	91.7 (84.3 to 99.7)	7.6	5,464	12.8	10,026	abcdefhijklmno
40-44	223	37.5 (32.9 to 42.8)	3.8	1,557	3.6	6,980	abcdefgijklmno
45-49	105	17.7 (14.6 to 21.4)	1.8	962	2.2	9,160	acdefghjklmno
50-54	40	6.7 (4.9 to 9.2)	0.7	405	0.9	10,136	abcdefghiklmno
55-59	21	3.5 (2.3 to 5.4)	0.4	125	0.3	5,937	abcdefghijlno
60-64	6	1.0 (0.5 to 2.2)	0.1	116	0.3	19,392	abcdefghijkm
65-69	24	4.0 (2.7 to 6.0)	0.4	10	0.0	398	abcdefghijlno
70-79	3	0.5 (0.2 to 1.6)	0.1	5	0.0	1,743	bcdefghijkm
80+	0	0.0 -	0.0	-	0.0	-	abcdefghijkm

CI: Confidence Interval. Significant differences ($p<0.05$) are with (**a**) 5-9; (**b**) 10-14; (**c**) 15-19; (**d**) 20-24; (**e**) 25-29; (**f**) 30-34; (**g**) = (35-39; (**h**) 40-44; (**i**) 45-49; (**j**)50-54; (**k**) 55-59; (**l**) 60-64; (**m**) 65-69; (**n**) 70-79; (**o**) 80+. Percentage totals do not equal 100% due to data rounding. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Total injury entitlement claims and costs by age and gender

There were significant differences in most of the age groups recorded for the total injury entitlement claims and costs. The 25-29 age group recorded 28% of total injury entitlement claims and 30% of total injury entitlement costs. This was slightly more than the 20-24 age group (27% claims; 25% costs) (see Table 28) (χ^2=0.134, df=1, p=0.71). The 20-24 age group recorded significantly more injury entitlement claims than the 15-19 age group (χ^2=125, df=1). Nearly 15% of total MSC injury entitlement claims and 20% of total costs were recorded from participants 35 years or older. The 60-64 age group recorded 0.1% of total injury entitlement claims, 0.3% of total injury entitlement costs but had the highest mean injury entitlement claim cost of $19,392 (£7,249) per claim. The most common age group for injury entitlement claims was the 25-29 age group for both male and female rugby league participants (see Figure 3).

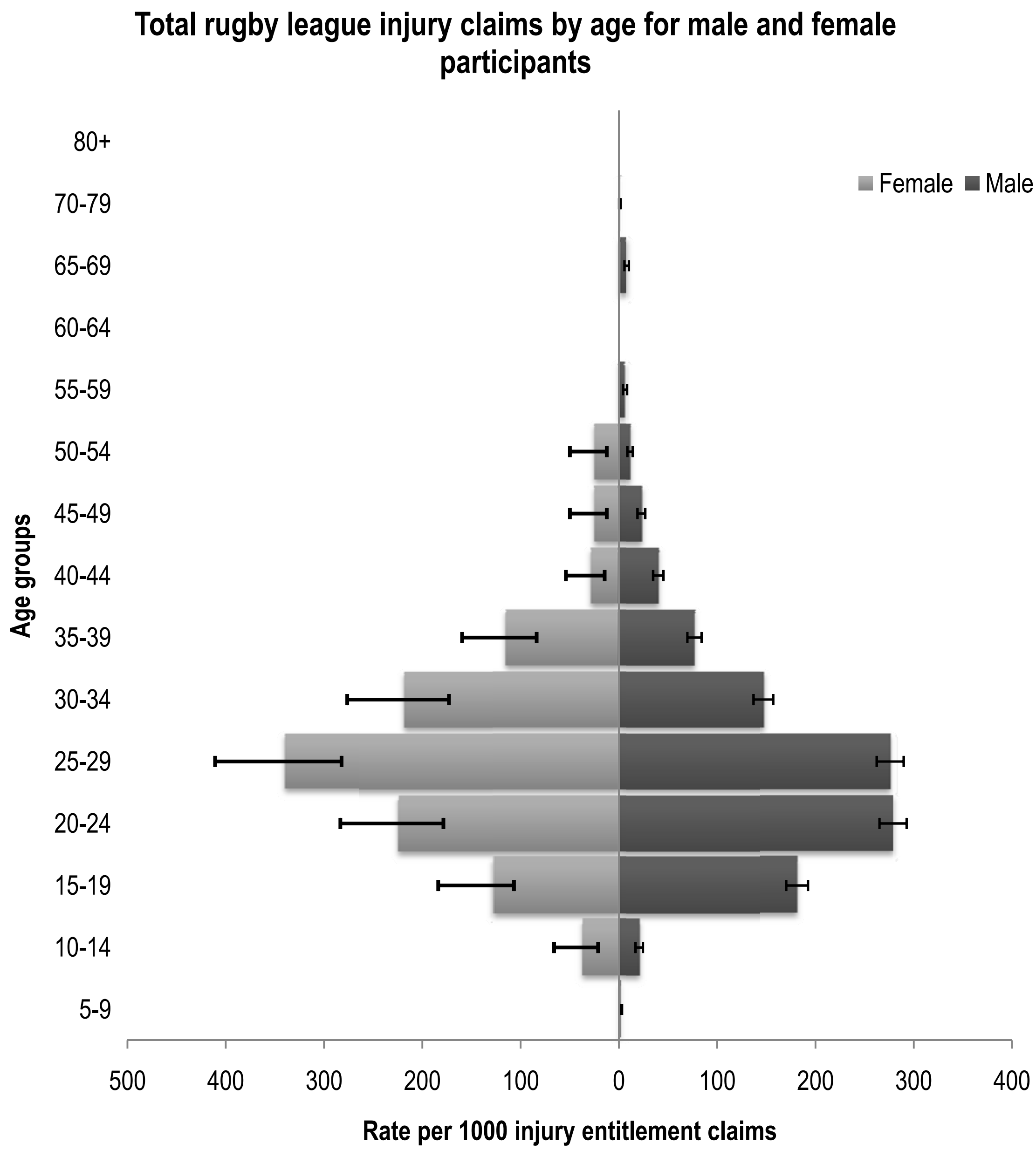

Figure 3: Incidence of rugby league injury entitlement claims with 95% confidence intervals for male and female: 1999-2007.

Discussion

This study identified the number of injury entitlement claims lodged and the associated costs of the injuries that have occurred from participation in rugby league activities in New Zealand over an eight year period.

The only recording mechanism for rugby league injuries in New Zealand is through the ACC earnings-related compensations claims files that are lodged when an injury is seen by a health care provider in New Zealand. The statistics gathered through the use of this system should not be seen as being reflective of the total incidence of injuries from rugby league participation in New Zealand.[169] The results could be biased as they exclude rugby league participants that do not make injury entitlement claims for more minor injuries.[169] However these results do highlight the number of injuries over an eight year recording period severe enough to require medical reporting. As there were no training or match related data, comparisons between costs of injury entitlement claims and training and match exposure time could not be undertaken. There was no indication as to whether the injury claims recorded were for new, recurrent or exacerbation of a previous injury. As can be seen the mean cost per claim of $7,206 (£2,678) was greater than the mean (£467 [$1,257]), median direct (£28[$76])[72] or median indirect (£77 [$207[)[72] costs per playing injury previously reported. This difference may be reflective of the limitations of previous studies identified by Gabbett[72] in the use of retrospective questionnaires,[135] player recall and small sample size.[72]

When comparing injury entitlement claims and costs for two time periods (2002-03 and 2006-07) there are several possible influences for the increase in injury claim incidence. The introduction of the Alliance competitions in 2004 may have resulted in an increase in matches which would increase exposure and could account for the increase in the number of injuries recorded. Another influence could be the cancellation of the New Zealand Rugby League Academy courses in 2003 which may have seen less people trained and qualified in roles such as Coach, Manager and Trainer. This may have resulted in less primary injury care at the sports fields from sports trainers resulting in more people presenting for treatment to medical providers who would claim to ACC for treatment costs provided. More research is required to fully establish the reasons why the injury entitlement claims and associated costs resulting from rugby league increased annually for the 2002-03 to 2006-07 reporting periods.

The incidence of injuries from rugby league participation has been reported using either a total[77, 152] (transient and missed match injuries) or a missed match[114, 193] injury definition. Injury incidence has ranged from 58[246] to 823[77] per 1000 playing hours in published studies using a total injury definition, compared to injury incidence of 1.4[213] to 197[148] per 1000 playing hours in published studies using a missed match injury definition. These differences reflect between 5%[58] to 32%[223] of the total injury incidence reported in published studies. As 14% of the total injury entitlement claims recorded were of MSC in this study this may be reflective of the cost of missed match and /or training injuries as a result of rugby league participation. When comparing the total number (42754) and cost ($48,704,704 [£18,204,395]) of rugby league injury entitlement claims, the mean total yearly injury entitlement costs of $1,473, ±$681 [£551, ±£255] was similar to previously reported mean costs,[72] but higher than the median (direct and indirect) costs[72] per playing injury. When comparing the non-MSC's for the same reporting period (36,811; $5,882,686 [£2,198,104]), the mean cost per non-MSC claim was $161, ±$34 (£60, ±£13) which was similar to the previously reported median direct and indirect costs.[72] This suggests that there are more costs incurred per playing injury than previously identified, or that the costs of treatment in New Zealand are higher than previously reported.[72]

Although the region of Auckland recorded 39% of the total MSC injury entitlement claims and 38% of the total MSC costs, the mean cost per MSC injury entitlement claim was less than Otago and Canterbury. Despite this, Otago recorded 2% of total MSC injury entitlement claims and 4% of total MSC costs. The high cost for Otago and Canterbury either reflects the different treatment costs for the district health boards, or that the injuries are more severe in Otago and Canterbury. Further indicators of the severity of injuries are required apart from our cost- method for approximation of injury severity.

Recent studies on rugby league match[152] and training[151] injuries identified that a team in Otago recorded more total[152] and missed match[152] injuries and more training total[151] and missed training[151] injuries than most,[58, 69, 137] but not all[77] published studies on rugby league injuries. Recent research[156] has identified that the injury risk rate more than doubled between New Zealand division 1 and division 2 teams for total injuries and tripled for missed match injuries. The increased injury rate was similar for Wellington (division 1) and Otago (division 2) when comparing the percentage of MSC injury entitlement claims (division 1: 7%; division 2: 2%) and total costs (division 1: 9%; division 2: 4%) for this study. The percentage of MSC injury entitlement claims for the division 1 region was more than triple that of the division 2 region and the costs more than double. The differences in costs may be reflective of the lower medical support provided at the sideline in the division 2 competitions when compared with a division 1 competition while the injuries recorded may be reflective of the different participation standards.

As has been reported in previous studies on rugby league injuries in Australia[115, 193, 223] and New Zealand,[148, 150, 154] the most commonly reported injury region was to the lower limbs. This was similar for lower limb injury MSC injury entitlement claims (42%) and costs (32%) while the head and neck recorded only 9% of claims but 22% of costs. The finding that the knee was the most common injury site conflicts with some[154, 169], but not all,[148-150] previous studies on rugby league injuries. The face was reportedly the most common injury claim site in a 1992 New Zealand study using ACC compensation claims[169] while the ankle was identified as the most common injury site in another early study on New Zealand rugby league injuries.[185] More recent New Zealand based studies on rugby league injuries identified the shoulder was the most common injury site recorded.[148, 150] This study found that the knee was the most commonly recorded injury site and the highest single injury cost site. The changes in injury site may be reflective of the changes observed in tackling style where traditionally participants tackled low on the body. More recently coaches have been teaching a higher body tackle technique in order to decrease second phase play, such as offloading of the ball and quick play-the-ball, in an attempt to slow down the opposition team's attacking options. Unfortunately, no information pertaining as to how the injury occurred (i.e., tackling, being tackled, collision, running, etc.) is gathered through the ACC data collection system. This is a limitation to this study and further longitudinal research is needed to fully explore if there is any relationship between tackle techniques and the incidence of injuries to the shoulder or head. When comparing mean costs per injury entitlement claim, the mean cost per MSC knee injury entitlement claim was less than the upper and lower arm, head (except face) and neck, back of head. The associated cost of head and neck related injuries highlights the need for more injury prevention programs targeting the head and neck area from the impact forces of collision sports.

Similar to the study conducted by Gabbett,[72] the majority of injuries recorded were musculoskeletal in nature. This is similar with all studies conducted on rugby league injuries[159]. Soft tissue injuries (sprains, strains, contusions and haematomas) and fracture-dislocations accounted for 92% of the total MSC rugby league injury entitlement claims and 80% of the total costs. This is reflective of the nature of rugby league where tackling, being tackled, acceleration, deceleration and change of direction are key components of rugby league at all levels of participation.[72] Although soft tissue injuries are the most common they are also easily provided for when an injury occurs. Reduction of swelling through the use of the RICE (rest, ice, compression, elevation) protocol can assist in the reduction of pain and injury severity.[170] Injury prevention programs promoting the RICE protocol could be routinely implemented to reduce the severity of soft tissue injuries that occur from rugby league participation.

Of concern was the cost of concussions over the study period. Although only accounting for 2% of the total MSC injury entitlement claims, concussions accounted for 6% of the total MSC costs and had the highest mean cost per injury type. Concussions have been reported to occur in 40% of all illegal tackles[132] with one study[185] reporting that all concussions recorded occurred in the tackle. Injury prevention strategies aimed at decreasing concussion in rugby league should include defensive drills,[72] tackle technique training.[72, 213] Further research is required on tackle direction, type and sites of contact;[212] player fatigue[231] and coach education programmes.[34]

Previous rugby league injury studies,[58, 78, 213] have reported that the incidence of injury increased as the participation age increased. Raftery et al.[213] identified that there was a sudden change in injury rate at the 11-12 age group which may have been a result of an increase in participant numbers. The effect of increased participant numbers may also be an explanation for the results of our study. This increase in injury can also be seen at both 10-14 and 15-19 age groups in this study. This may be due to the changes of opportunities and exposure to rugby league in New Zealand with the introduction of the professional club, the New Zealand Warriors, encouraging more young players to participate. The increase in the number of Auckland-based rugby league competitions would account for the higher injury claim rate when compared with the other districts. It is unfortunate that the different participation levels in the districts are not readily available with which to compare the ACC injury data.

Masters rugby league is a recently participated competition for players over the age of 35 years old. Unfortunately no published studies have been conducted on this level of participation. This study identified that 15% of total MSC injury entitlement claims and 20% of total costs were recorded from participant's aged over 35 years. The top four mean cost per MSC injury entitlement claims were recorded in age groups that would primarily participate in the Master's level of competitions. Research into this level of participation is warranted to identify the risks and injury incidence that occur in Masters rugby league.

Conclusions

This study explored the injury entitlement rate, costs, site, type, geographic district and age of injured participants in rugby league in New Zealand. While this is important in understanding what costs are incurred and what injuries were sustained across injury sites, injury types, age categories, and regions in the country over a period of years, the data do not present: (1) How the injuries occurred; (2) What participation level the injuries occurred in; (3) Whether the injuries occurred as a result of match or training activities; nor (4) At what stage of the match the injuries occurred. Further longitudinal epidemiological studies with specific details on injury mechanisms and participation data are warranted to further explore the incidence of injury that occur from rugby league participation in New Zealand.

CHAPTER 5: RUGBY LEAGUE INJURIES IN NEW ZEALAND: VARIATIONS IN INJURY CLAIMS AND COSTS BY ETHNICITY, GENDER, AGE, DISTRICT, BODY SITE, INJURY TYPE AND OCCUPATION

This chapter comprises the following paper accepted by the *New Zealand Journal of Sports Medicine.*

Reference

King, D., Hume, P., Milburn, P. & Gianotti, S. Rugby league injuries in New Zealand: variations in injury claims and costs by ethnicity, gender, age, district, body site, injury type and occupation. *New Zealand Journal of Sports Medicine.* 2009. **36**(2): 48-55

Author contributions

King, D. 70%; Hume, P. 15%; Milburn, P. 10%; Gianotti, S. 5%

Overview

This study provides an overview of the epidemiology of New Zealand rugby league injuries requiring medical treatment and associated costs analysed by ethnic groups. New Zealand national Accident Compensation Corporation injury data for the period 1999 to 2007 were searched for rugby league injury cases. Data were analysed by ethnic groups for demographics, body region, nature/severity of injury, and medical procedure and costs. New Zealand Maori accounted for 40% of the number of total injury claims and 44% of the total injury entitlement costs but were recorded as only 13% of the total New Zealand population. Accounting for only 3% of the population distribution living in Auckland, New Zealand Maori recorded 12% of the total injury claims in the Auckland district. Soft tissue injuries accounted for 11%, ±9% of injury claims and 8%, ±7% of injury entitlement costs for all ethnic groups. New Zealand Maori recorded more injury claims for the knee than all other ethnic groups. Injury claims for New Zealand Europeans recorded more trade occupations, New Zealand Maori more plant and machinery occupations and Pacific peoples more elementary occupations. New Zealand Maori recorded significantly more injury claims for both males and females than all other ethnic groups over the study period. This study identified the number of injury claims, and associated costs of the injuries, by ethnic group that have occurred from participation in rugby league activities in New Zealand over an eight year period. NZ Maori are disproportionately participating in rugby league in NZ, but the proportions injured are consistent with reported proportions playing the game. Further research is warranted to fully explore the differences in injury rate between the ethnic groups and to what extent these differences in levels of participation in rugby league activities.

Introduction

The use of sports injury surveillance to provide epidemiological data is useful in describing the occurrence of injuries and associated risk factors[199] and in directing and monitoring the effectiveness of programs designed to reduce the risk of injury from participation in sporting activities.[53, 244] Sports injury reduction programs include modifying coaching material and training resources,[113] modifying training techniques[172, 184] and equipment[142] and implementing law changes in sporting activities.[237]

Studies undertaken on rugby league injuries have looked at the incidence of injuries in both the match and training environments;[78, 87, 151] changes in injury incidence as a result of changes in playing season,[119, 134] rule changes,[198] different participation levels;[78, 87, 223] anthropometric and physiological characteristics of rugby league participants,[104] and the cost of injuries from rugby league participation.[72, 182] A recent national epidemiological analysis of eight years (1999-2007) of moderate to serious injury claims lodged with the Accident Compensation Corporation (ACC) for rugby league injury in New Zealand[157] showed that the knee was the most common injury site and soft tissue injuries were the most common injury type. Concussions contributed 2% of total injury claims but 6% of injury entitlement costs and had the highest mean cost per claim ($25,347 [£9,420]). Despite the increasing number of international studies on rugby league no study has looked at the incidence of injuries of different ethnic groups as a result of participation in rugby league activities. We were interested in any differences in injury incidence and characteristics by ethnicity given the differences in proportions of ethnicities playing rugby league[59] compared to the proportions of ethnicities in the New Zealand population.[1] In the New Zealand population of 4.1 million[1] in 2006 the reported four largest ethnic groups were New Zealand Europeans (68%), New Zealand Maori (15%), Pacific Peoples (7%) and Asian (9%), whilst in the New Zealand Rugby League participation population 42% were reported as New Zealand Maori, 32% New Zealand European, 22% Pacific and 4% are other.[59].

With this in mind, the aim of this study was to provide an epidemiological overview of rugby league injuries and associated costs in one country (New Zealand) by ethnic groups over an eight year period (1999 to 2007). New Zealand's national no-fault injury compensation system administered by the Accident Compensation Corporation (ACC) means that New Zealand is uniquely positioned to provide detail descriptive epidemiological data, including costs associated with treatment, on sports (such as rugby league) injuries. Using this data, comparisons by ethnic group for the rate, site, type, cost, location and occupation of players for rugby league injuries were conducted.

Data limitations

Epidemiological studies are dependant on data quality for any analysis to be undertaken.[112] The data provided for the analysis in this study are from the ACC database and are dependant on several factors.[157] Additionally, data were limited to the ACC database only as there were no other available databases for the collection of player specific data such as: (1) Numbers participating in rugby league activities; (2) Age of players participating; (3) Identification of the ethnicity of players; and (4) Number of matches played and trainings completed enabling match and training exposure hours.

Methods

ACC cover is available to any person, including visitors to New Zealand, that suffers any accidental personal injury at any time when in New Zealand. People who have a personal injury can make a claim to ACC at the time of seeking medical treatment from over 30,000 registered health professionals throughout New Zealand. When making a claim, information about the injury is collected using a standard ACC 45 injury reporting form to ensure levels of consistency for data recording and analyses. The injured person (unless impaired) completes information about the activity surrounding the injury (e.g., location, activity prior, cause, narrative) along with their personal details (e.g., age, gender, ethnicity, contact details). The registered health professional completes the form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and details are entered into a central database.

ACC makes no disincentive for making claims nor are people risk-rated or penalised for the amount of claims they make.[111] Personal injury coverage is guaranteed by ACC but this is offset by the restriction to sue for personal injury, except in rare circumstances, for exemplary damages.[111] ACC categorises the claims made as minor or moderate to serious claims (MSC) and as new or ongoing injury claims. Minor injury claims reflect those injuries that require the initial medical treatment or service and may only require one or two visits to a health professional. Moderate to serious injury claims reflect those injuries that require additional treatment than the initial medical treatment or service, for example income replacement if the injury requires more than five consecutive days off work. Serious injury claims are permanent brain injury or spinal damage. New claims are those made in the reporting period and are reflective of the number of new injuries from rugby league participation. Ongoing injury claims are reflective of the severity of the injury claim and can carry on over the reporting period. In this study MSCs are reported with new and ongoing injuries combined per reporting period.

Throughout the study period there were 42754 new and ongoing claims costing ACC $NZD 48,704,704 [£GBP18,099,470]. MSC represented 14% (5941) of the number of total claims but 88% ($NZD 42,822,048 [£GBP15,916,048]) of the costs. For this study we focused on MSC rather than minor claims as defined by the ACC for its sports cost outcome model,[111] that occurred between 1st July 1999 and the 30th June 2007 as a result of participating in rugby league activities. ACC data were analysed by ethnic groups for: (1) Region/District; (2) Injury type; (3) Injury site and (4) Occupation[128] (see Table 1). A potential limitation to the ACC data are the way the data are retrieved to protect client confidentiality by limiting the access to low level results under four injury claims. Therefore any data less than or equal to three injury claims have been rounded to represent three claims only. New Zealand population data were obtained from official government data. This data set provides estimates of resident populations between each five year census.[1] The population of New Zealand over the study period was approximately 4.1 million people based on the 2006 census.[1] Rugby player participation proportions were based on the published work of Falcous.[59]

Table 29: Data categories analysed.

Ethnicity		Region		Injury site		Injury type	Occupation
Group	includes	Area	District	Group	Sub-group		NZSCO categories[128]
New Zealand European		**North Island**		**Head/Neck**		Soft tissue injury	Legislators, Administrators, and Managers
New Zealand Maori			Northland		Head (except face)	Corrosive injuries	Professionals
Pacific Peoples			Auckland		Face	Dental injuries	Technicians and Associate Professionals
	Cook Island Maori		Waikato		Eye	Fracture / Dislocation	Clerks
	Tongan		Bay of Plenty		Nose	Hernia	Service and Sales Workers
	Niuean		Gisborne		Ear	Laceration, puncture, wound, sting	Agriculture and Fishery Workers
	Fijian		Hawke's Bay		Neck / Back of head / vertebrae	Foreign body in orifice / eye	Trades Workers
	Tokelauan		Taranaki	**Upper Limb**		Concussion / brain injury	Plant and Machine Operators and Assemblers
	Other Pacific		Manawatu-Wanganui		Shoulder (including Clavicle/Shoulder blade)	Amputation	Elementary Occupations
Asian			Wellington		Upper and Lower Arm	Deafness	Unknown
	South East Asian	**South Island**			Elbow	Other/Unknown	
	Indian		Tasman		Hand / wrist		
Other/Unknown			Nelson		Finger / Thumb		
			Marlborough	**Lower Limb**			
			Canterbury		Hip/Upper leg/Thigh		
			West Coast		Knee		
			Otago		Lower Limb		
			Southland		Ankle		
		Other/Unknown			Foot		
					Toes		
				Other			
					Abdomen / Pelvis		
					Chest		
					Back / Spine		
					Internal organ		
					Multiple locations		
				Unknown			

Ethical consent

Ethical consent for the research was obtained from the Auckland University of Technology Ethics Committee. Informed consent from the injured participants was not obtained as data were collected from the ACC data base without individual player identification or follow-up.

Statistical analyses

All the data collected were entered into a Microsoft Excel spreadsheet and analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of injuries per 1000 injury claims.[114, 135, 136] Data are reported as means with 95% confidence intervals (CI).[240] The injury rates and patterns were compared between reporting years using a one sample chi-squared (χ^2) test. Significant p values reported in the text are less than 0.001 if they are not specifically stated. Injury incidence was not calculated for the study as rugby league participation rates were not available as part of the data analysis. All costs are reported in New Zealand Dollars ($) and Great Britain Pounds (£) unless otherwise indicated.

Results

Over the study period, there were 5941 new and ongoing moderate to serious injury claims recorded. New Zealand Maori recorded significantly more injury claims than all other ethnic groups (see Table 30).[1] They accounted for 40% of the number of total injury claims and 44% of the total injury entitlement costs but were recorded as only 13% of the total population. All other ethnic groups accounted for fewer claims and costs. New Zealand European (χ^2=267, df=7) and New Zealand Maori (χ^2=183, df=7) recorded a decrease in the incidence of injury claims over the duration of the study while Pacific Peoples (χ^2=169, df=7) and Asian (χ^2=18, df=7) recorded an increase (see Table 31).

Table 30: Total injury rate per 1000 entitlement claims, 95% Confidence Intervals and percentage of total claims, costs, percentage of total costs and mean cost per claim by ethnic groups from 1999 to 2007.

	Population Distribution	Injury Claims						Difference from Ethnic Group[1]				
		Total Claims			Total Costs $(000)			NZ European	NZ Maori	Pacific people	Asian	Other
Ethnic Group	**%[1]**	**Number**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean**	**χ^2 (df=1)**	**χ^2 (df=1)**	**χ^2 (df=1)**	**χ^2 (df=1)**	**χ^2 (df=1)**
New Zealand European	61.2	1839	309.6 (295.8 to 324.1)	31	12,377	28.9	6.7	-				
New Zealand Maori	13.2	2365	398.1 (382.4 to 414.5)	39.8	18,615	43.5	7.8	65	-			
Pacific Peoples	6.2	1280	215.5 (204.1 to 227.7)	21.5	8,304	19.4	6.4	100	323	-		
Asian	8.4	33	5.9 (4.2 to 8.2)	0.6	113	0.3	3.2	1742	2268	1184	-	
Other/Unknown	10.9	424	71.7 (65.2 to 78.8)	7.1	3,413	7.9	8	88.4	1350	430	335	-
Total	**100**	**5491**	**1000.0 (974.9 to 1025.8)**	**100**	**42,822**	**100**	**7.2**					

CI: Confidence Interval. Rates are per 1000 injury claims. 1= p values all <0.001. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 31: Total injury claims by reporting year per 1000 entitlement claims, 95% Confidence Intervals and costs for ethnic groups from 1999 to 2007.

	New Zealand European			New Zealand Maori			Pacific Peoples			Asian			Other		
Yr	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**
99-00	228	325.3 (319.4 to 414.0)	1,312	245	390.7 (344.8 to 442.9)	1,681	110	175.4 (145.5 to 211.5)	626	3	4.8 (1.5 to 14.8)	2	43	68.6 (50.9 to 92.5)	188
00-01	155	363.6 (245.7 to 336.6)	911	229	424.9 (373.2 to 483.6)	1,772	112	209.6 (174.3 to 252.1)	706	5	11.1 (5.0 to 24.8)	25	40	74.2 (54.4 to 101.2)	202
01-02	138	287.6 (232.2 to 324.2)	841	235	467.2 (411.1 to 530.9)	1,724	107	214.7 (177.8 to 259.3)	890	0	0.0 -	0	22	43.7 (28.8 to 66.4)	227
02-03	142	274.4 (250.3 to 347.4)	1,064	193	400.0 (347.5 to 460.4)	1,754	115	239.2 (199.4 to 286.9)	673	0	0.0 -	0	32	68.0 (48.4 to 95.7)	147
03-04	160	294.8 (221.4 to 301.8)	1,142	275	444.3 (394.7 to 500.0)	2,080	139	224.6 (190.2 to 265.2)	861	3	4.8 (1.6 to 15.0)	2	42	67.9 (50.1 to 91.8)	240
04-05	305	258.5 (288.5 to 361.1)	1,784	356	376.7 (339.6 to 418.0)	2,452	200	211.6 (184.3 to 243.1)	1,207	5	6.3 (2.9 to 14.1)	16	77	81.5 (65.2 to 101.9)	343
05-06	322	322.8 (271.6 to 337.9)	2,405	410	385.7 (350.1 to 424.9)	2,630	243	228.6 (201.6 to 259.2)	1,565	8	7.5 (3.8 to 15.0)	36	80	75.3 (60.4 to 93.7)	720
06-07	390	302.9 (303.9 to 370.6)	2,913	422	363.2 (330.1 to 399.5)	4,517	254	218.6 (193.3 to 247.2)	1,781	9	7.7 (4.0 to 14.9)	28	88	75.7 (61.5 to 93.3)	1,294
Total	**1839**	**309.6 (295.89 to 324.1)**	**12,377**	**2365**	**398.1 (382.4 to 414.5)**	**18,615**	**1280**	**215.5 (204.1 to 227.7)**	**8,304**	**33**	**5.9 (4.2 to 8.2)**	**113**	**424**	**71.7 (65.2 to 78.86)**	**3,413**

CI: Confidence Interval. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence

Total injury claims by district and ethnicity

Accounting for only 3% of the population distribution living in Auckland, New Zealand Maori recorded 12% of the total injury claims in the Auckland District (see Table 32). This was similar for New Zealand Maori in all other North Island districts. In the South Island, New Zealand Maori recorded more total injury claims in Canterbury (4%) but accounted for only 0.9% of the population distribution. This was similar for Pacific Peoples in Auckland (claims: 14%; population: 4%) Wellington (claims: 2%; population 0.8%) and Canterbury (claims: 2% population 0.3%). All other districts and ethnic groups had a similar percentage distribution for both injury claims and population distribution.

Total injury claims by injury type and ethnicity

Soft tissue injuries accounted for 11%, ±9% of injury claims and 8%, ±7% of injury entitlement costs for all ethnic groups (see Table 33). Fracture dislocations (claims: 10%, ±8%; costs: 8%, ±6%), concussions (claims: 0.5%, ±0.4; costs: 1%, ±2%) and lacerations & wounds (claims: 0.5%, ±0.4%; costs: 0.2% ±0.1%) were slightly less. New Zealand Maori recorded more soft tissue injuries (χ^2=1500, df=4), fracture-dislocations (χ^2=1311, df=4) and concussions (χ^2=72, df=4) than other ethnic groups and these were significant.

Total injury claims by injury site and ethnicity

More injury claims were made for injuries to the lower than the upper limbs for most (New Zealand European: χ^2=6, df=1, p=0.012; New Zealand Maori: χ^2=0, df=1, p=0.765; Pacific Peoples: χ^2=8, df=1, p=0.004; Asian: χ^2=0.6, df=1, p=0.414) ethnic groups (see Table 34). The knee was the most common injury site recorded for all ethnic groups over the study period. New Zealand Maori recorded more injury claims for the knee than all other ethnic groups (χ^2=683, df=4). Although New Zealand Maori recorded more total head and neck injury claims than all other ethnic groups (χ^2=303, df=4), New Zealand Europeans recorded more neck (χ^2=105, df=1) and face (χ^2=63, df=1) injury claims.

Table 32: Total population percentage by district and injury claims by district per 1000 entitlement claims, 95% Confidence Intervals, costs and percentage of injury claims for ethnic groups from 1999 to 2007.

	New Zealand European				New Zealand Maori				Pacific Peoples				Asian				Other / Unknown			
	P%	No. [Rate(95% CI)]	$(000)	%	P%	No. [Rate(95% CI)]	$(000)	%	P%	No. [Rate(95% CI)]	$(000)	%	P%	No. [Rate(95% CI)]	$(000)	%	P%	No. [Rate(95% CI)]	$(000)	%
North Island	43.9	1129 [190.0(179.3 to 201.5)]	6949	19.0	11.5	2021 [340.2(325.7 to 355.3)]	15584	34.0	5.8	1082 [182.1(171.6 to 193.3)]	6553	18.2	7.4	29 [4.9(3.4 to 7.0)]	86	0.5	7.6	295 [49.7(44.3 to 55.7])	3012	5.0
Northland	2.2	46 [7.7(5.8 to 10.3)]	183	0.8	1	145 [24.4(20.7 to 28.7)]	499	2.4	0.1	18 [3.0(1.9 to 4.8)]	190	0.3	0.1	0 [0.0 to]	0	0.0	0.4	31 [5.2(3.7 to 7.4)]	47	0.5
Auckland	16.4	637 [107.2(99.2 to 115.9)]	4585	10.7	3.2	698 [117.5(109.1 to 126.6)]	6113	11.7	4.2	817 [137.5(128.4 to 147.3)]	3997	13.8	5.5	20 [3.4(2.2 to 5.2)]	56	0.3	2.8	148 [24.9(21.2 to 29.3)]	1629	2.5
Waikato	6	133 [22.4(18.9 to 26.5)]	525	2.2	1.8	338 [56.9(51.1 to 63.3)]	2599	5.7	0.3	35 [5.9(4.2 to 8.2)]	197	0.6	0.4	2 [0.3(0.1 to 1.3)]	1	0.0	1	41 [6.9(5.1 to 9.4)]	869	0.7
Bay of Plenty	3.9	73 [12.3(9.8 to 15.5)]	529	1.2	1.6	231 [38.9(34.2 to 44.2)]	1611	3.9	0.2	38 [6.4(4.7 to 8.8)]	167	0.6	0.2	0 [0.0 -]	0	0.0	0.7	21 [3.5(2.3 to 5.4)]	118	0.4
Gisborne	0.5	8 [1.3(0.7 to 2.7)]	6	0.1	0.5	62 [10.4(8.1 to 13.4)]	275	1.0	0	2 [0.3(0.1 to 1.3)]	44	0.0	0	0 [0.0-]	0	0.0	0.1	5 [0.8(0.4 to 2.0)]	67	0.1
Hawke's Bay	2.3	16 [2.7(1.7 to 4.4)]	85	0.3	0.8	86 [14.5(11.7 to 17.9)]	374	1.4	0.1	13 [2.2(1.3 to 3.8)]	101	0.2	0.1	0 [0.0-]	0	0.0	0.4	5 [0.8(0.4 to 2.0)]	45	0.1
Taranaki	1.8	55 [9.3(7.1 to 12.1)]	205	0.9	0.4	123 [20.7(17.4 to 24.7)]	1008	2.1	0	6 [1.0(0.5 to 2.2)]	17	0.1	0.1	0 [0.0-]	0	0.0	0.3	9 [1.5(0.8 to 2.9)]	58	0.2
Manawatu	3.7	77 [13.0(10.4 to 16.2)]	445	1.3	1	139 [23.4(19.8 to 27.6)]	1662	2.3	0.1	20 [3.4(2.2 to 5.2)]	75	0.3	0.2	0 [0.0-]	0	0.0	0.7	10 [1.7(0.9 to 3.1)]	16	0.2
Wellington	7.1	84 [14.1(11.4 to 17.5)	386	1.4	1.3	199 [33.5(29.2 to 38.5)]	1443	3.3	0.8	133 [22.4(18.9 to 26.5)]	1765	2.2	0.9	7 [1.2(0.6 to 2.5)]	29	0.1	1.2	25 [4.2(2.8 to 6.2)]	163	0.4
South Island	17.3	678 [114.1(105.8 to 123.0)]	4734	11.4	1.7	306 [51.5(46.0 to 57.6)]	2437	5.2	0.4	158 [26.6(22.8 to 31.1)]	1287	2.7	1	4 [0.7(0.3 to 1.8)]	21	0.1	3.3	122 [20.5(17.2 to 24.5)]	714	2.1
Tasman	0.8	1 [0.2(0.0 to 1.2)]	7	0.0	0.1	2 [0.3(0.1 to 1.3)]	6	0.0	0	0 [0.0-]	0	0.0	0	0 [0.0 -]	0	0.0	0.2	0 [0.0-]	0	0.0
Nelson	0.8	8 [1.3(0.7 to 2.7)]	32	0.1	0.1	7 [1.2(0.6 to 2.5)]	44	0.1	0	3 [0.5(0.2 to 1.6)]	7	0.1	0	0 [0.0-]	0	0.0	0.1	4 [0.7(0.3 to 1.8)]	24	0.1
Marlbourgh	0.8	9 [1.5(0.8 to 2.9)]	67	0.2	0.1	5 [0.8(0.4 to 2.0)]	21	0.1	0	0 [0.0-]	0	0.0	0	0 [0.0-]	0	0.0	0.2	2 [0.3(0.1 to 1.3)]	12	0.0
Canterbury	9.2	450 [75.8(69.1 to 83.1)]	2671	7.6	0.9	241 [40.6(35.8 to 46.0)]	2133	4.1	0.3	129 [21.7(18.3 to 25.8)]	1150	2.2	0.7	4 [0.7(0.3 to 1.8)]	21	0.1	1.7	87 [14.6(11.9 to 18.1)]	597	1.5
West Coast	0.6	100 [16.8(13.8 to 20.5)]	541	1.7	0.1	5 [0.8(0.4 to 2.0)]	56	0.1	0	1 [0.2(0.0 to 1.2)]	1	0.0	0	0 [0.0-]	0	0.0	0.1	7 [1.2(0.6 to 2.5)]	30	0.1
Otago	3.5	81 [13.6(11.0 to 17.0)]	1285	1.4	0.3	25 [4.2(2.8 to 6.2)]	83	0.4	0.1	20 [3.4(2.2 to 5.2)]	103	0.3	0.2	0 [0.0-]	0	0.0	0.6	12 [2.0(1.1 to 3.6)]	23	0.2
Southland	1.6	29 [4.9(3.4 to 7.0)]	131	0.5	0.2	21 [3.5(2.3 to 5.4)]	94	0.4	0	5 [0.8(0.4 to 2.0)]	26	0.1	0	0 [0.0-]	0	0.0	0.3	10 [1.7(0.9 to 3.1)]	29	0.2
Other / Unknown	0	32 [5.4(3.8 to 7.6)]	383	0.5	0	38 [6.4(4.7 to 8.8)]	252	0.6	0	40 [6.7(4.9 to 9.2)]	314	0.7	0	0 [0.0-]	0	0.0	0	7 [1.2(0.6 to 2.5)]	10	0.1

CI: Confidence Interval. Rates are per 1000 injury claims. P% = Percentage of population from Census 2006[1]; $(000) expressed in New Zealand Dollars. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 33: Total injury claims by injury type per 1000 entitlement claims, 95% Confidence Intervals and costs for ethnic groups from 1999 to 2007.

	New Zealand European			New Zealand Maori			Pacific peoples			Asian			Other / Unknown		
	No.	**Rate (95% CI)**	**$(000)**	**No.**	**Rate (95% CI)**	**$(000)**	**No.**	**Rate (95% CI)**	**$(000)**	**No.**	**Rate (95% CI)**	**$(000)**	**No.**	**Rate (95% CI)**	**$(000)**
Soft tissue Injuries	980	164.9 (154.9 to 175.6)	5,377	1110	186.8 (176.1 to 198.1)	7,002	595	100.1 (92.4 to 108.5)	3,396	29	4.9 (3.4 to 7.0)	52	214	36.0 (31.5 to 41.2)	1,174
Fracture / Dislocations	887	149.3 (139.7 to 159.4)	5,220	1032	173.6 (163.4 to 184.6)	6,503	568	95.6 (88.0 to 103.8)	3,375	28	4.7 (3.3 to 6.8)	57	231	38.9 (34.2 to 44.2)	1,776
Other/Unknown	102	17.2 (13.1 to 22.5)	1,618	121	20.4 (15.9 to 26.1)	2,592	75	12.6 (9.3 to 17.3)	999	0	0.0 -	-	23	3.9 (2.6 to 5.8)	3,363
Concussion / Brain injury	41	6.9 (5.1 to 9.4)	86	62	10.4 (8.1 to 13.4)	2,363	17	2.9 (1.8 to 4.6)	44	0	0.0 -	-	31	5.2 (3.7 to 7.4)	239
Lacerations / Wounds	48	8.1 (6.1 to 10.7)	2	42	7.1 (5.2 to 9.6)	111	30	5.0 (3.5 to 7.2)	108	0	0.0 -	-	14	2.4 (1.4 to 4.0)	11
Dental Injuries	20	3.4 (2.2 to 5.2)	18	6	1.0 (0.5 to 2.2)	15	24	4.0 (2.7 to 6.0)	385	0	0.0 -	-	0	0.0 -	-
Deafness	0	0.0-	-	13	2.2 (1.3 to 3.8)	14	0	0 -	-	0	0.0 -	-	0	0.0 -	-
Hernia	8	1.3 (0.7 to 2.7)	4	3	0.5 (0.2 to 1.6)	4	0	0 -	-	0	0.0 -	-	0	0.0 -	-
Corrosive Injuries	0	0.0-	-	3	0.5 (0.2 to 1.6)	3	0	0 -	-	0	0.0 -	-	0	0.0 -	-
Foreign body	0	0.0-	-	3	0.5 (0.2 to 1.6)	1	0	0 -	-	0	0.0 -	-	0	0.0 -	-

CI: Confidence Interval. Rates are per 1000 injury claims; $(000) expressed in New Zealand Dollars. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 34: Total injury claims by injury site per 1000 entitlement claims, 95% Confidence Intervals and costs for ethnic groups from 1999 to 2007.

	New Zealand European			New Zealand Maori			Pacific Peoples			Asian			Other / Unknown		
Body Site	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**	**No**	**Rate (95% CI)**	**$(000)**
Head & Neck	**239**	**40.2 (35.4 to 45.7)**	**2,438**	**245**	**41.2 (36.4 to 46.7)**	**4,138**	**126**	**21.2 (17.8 to 25.3)**	**1,153**	**3**	**0.5 (0.2 to 1.6)**	**2**	**88**	**14.8 (12.0 to 18.3)**	**1,288**
Head (except face)	37	6.2 (4.5 to 8.6)	86	73	12.3 (9.8 to 15.5)	3,302	29	4.9 (3.4 to 7.0)	403	0	0.0 -	0	27	4.5 (3.1 to 6.6)	242
Neck, Back of head	85	14.3 (11.6 to 17.7)	2,138	56	9.4 (7.3 to 12.2)	614	35	5.9 (4.2 to 8.2)	274	0	0.0 -	0	23	3.9 (2.6 to 5.8)	980
Face	61	10.3 (8.0 to 13.2)	116	42	7.1 (5.2 to 9.6)	82	38	6.4 (4.7 to 8.8)	443	3	0.5 (0.2 to 1.6)	2	17	2.9 (1.8 to 4.6)	19
Eye	12	2.0 (1.1 to 3.6)	16	27	4.5 (3.1 to 6.6)	48	9	1.5 (0.8 to 8.0)	8	0	0.0 -	0	0	0.0 -	0
Ear	0	0.0 -	0	21	3.5 (2.3 to 5.4)	35	3	0.5 (0.2 to 1.6)	2	0	0.0 -	0	0	0.0 -	0
Nose	44	7.4 (5.5 to 10.0)	82	26	4.4 (3.0 to 6.4)	58	12	2.0 (1.1 to 3.6)	23	0	0.0 -	0	21	3.5 (2.3 to 5.4)	47
Upper Limb	**774**	**130.3 (121.4 to 139.8)**	**3,887**	**939**	**158.1 (148.3 to 168.5)**	**5,259**	**480**	**80.8 (73.9 to 88.4)**	**2,312**	**24**	**4.0 (2.7 to 6.0)**	**44**	**196**	**33.0 (28.7 to 37.9)**	**728**
Shoulder	353	59.4 (53.5 to 66.0)	2,052	403	67.8 (61.5 to 74.8)	3,208	204	34.3 (29.9 to 39.4)	1,113	11	1.9 (1.0 to 3.3)	32	87	14.6 (11.9 to 18.1)	402
Upper & Lower arm	93	15.7 (12.8 to 19.2)	660	127	21.4 (18.0 to 25.4)	640	78	13.1 (10.5 to 16.4)	425	0	0.0 -	0	42	7.1 (5.2 to 9.6)	144
Elbow	37	6.2 (4.5 to 8.6)	266	44	7.4 (5.5 to 10.0)	118	28	4.7 (3.3 to 6.8)	99	0	0.0 -	0	5	0.8 (0.4 to 2.0)	5
Hand/wrist	164	27.6 (23.7 to 32.2)	624	221	37.2 (32.6 to 42.4)	849	116	19.5 (16.3 to 23.4)	474	13	2.2 (1.3 to 3.8)	12	41	6.9 (5.1 to 9.4)	137
Finger/Thumb	127	21.4 (18.0 to 25.4)	285	144	24.2 (20.6 to 28.5)	444	54	9.1 (7.0 to 11.9)	201	0	0.0 -	0	21	3.5 (2.3 to 5.4)	40
Lower Limb	**876**	**147.4 (138.0 to 157.5)**	**4,116**	**952**	**160.2 (150.4 to 170.8)**	**5,091**	**573**	**96.4 (88.9 to 104.7)**	**2,993**	**30**	**5.0 (3.5 to 7.2)**	**63**	**185**	**31.1 (27.0 to 36.0)**	**1,216**
Hip, Upper leg, Thigh	59	9.9 (7.7 to 12.8)	174	42	7.1 (5.2 to 9.6)	139	28	4.7 (3.3 to 6.8)	134	0	0.0 -	0	21	3.5 (2.3 to 5.4)	46
Knee	469	78.9 (72.1 to 86.4)	2,739	484	81.5 (74.5 to 89.1)	3,290	303	51.0 (45.6 to 57.1)	1,826	11	1.9 (1.0 to 3.3)	36	91	15.3 (12.5 to 18.8)	854
Lower Leg	117	19.7 (16.4 to 23.6)	446	139	23.4 (19.8 to 27.6)	579	70	11.8 (9.3 to 14.9)	380	10	1.7 (0.9 to 3.1)	8	30	5.0 (3.5 to 7.2)	79
Ankle	194	32.7 (28.4 to 37.6)	714	241	40.6 (35.8 to 46.0)	996	147	24.7 (21.0 to 29.1)	596	9	1.5 (0.8 to 2.9)	18	37	6.2 (4.5 to 8.6)	234
Foot	34	5.7 (4.1 to 8.0)	42	39	6.6 (4.8 to 9.0)	86	25	4.2 (2.8 to 6.2)	59	0	0.0 -	0	0	0.0 -	0
Toes	3	0.5 (0.2 to 1.6)	1	7	1.2 (0.6 to 2.5)	2	0	0.0 -	0	0	0.0 -	0	6	1.0 (0.5 to 2.2)	3
Chest, Back, Other	**197**	**33.2 (28.8 to 38.1)**	**1,415**	**259**	**43.6 (38.6 to 49.2)**	**2,054**	**130**	**21.9 (18.4 to 26.0)**	**911**	**0**	**0.0 -**	**0**	**48**	**8.1 (6.1 to 10.7)**	**49**
Chest	48	8.1 (6.1 to 10.7)	70	91	15.3 (12.5 to 18.8)	116	25	4.2 (2.8 to 6.2)	33	0	0.0 -	0	21	3.5 (2.3 to 5.4)	31
Back/Spine	68	11.4 (9.0 to 14.5)	1,229	78	13.1 (10.5 to 16.4)	1,931	29	4.9 (3.4 to 7.0)	827	0	0.0 -	0	9	1.5 (0.8 to 2.9)	15
Abdomen/Pelvis	15	2.5 (1.5 to 4.2)	91	9	1.5 (0.8 to 2.9)	5	12	2.0 (1.1 to 3.6)	52	0	0.0 -	0	3	0.5 (0.2 to 1.6)	3
Internal organs	12	2.0 (1.1 to 3.6)	24	0	0.0 -	0	3	0.5 (0.2 to 1.6)	<0.5	0	0.0 -	0	0	0.0 -	0
Multiple Injuries	0	0.0 -	0	4	0.7 (0.3 to 1.8)	2	0	0.0 -	0	0	0.0 -	0	0	0.0 -	0
Unknown	**54**	**9.1 (7.0 to 11.9)**	**516**	**77**	**13.0 (10.4 to 16.2)**	**1,837**	**61**	**10.3 (8.0 to 13.2)**	**808**	**0**	**0.0 -**	**0**	**15**	**2.5 (1.5 to 4.2)**	**81**

CI: Confidence Interval. Rates are per 1000 injury claims. Totals do not equal due to data rounding; $(000) expressed in New Zealand Dollars. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Total injury claims by occupation and ethnicity

Occupational injury claims varied by ethnic groups. New Zealand Europeans recorded more injuries for trade workers (χ^2=551, df=4), New Zealand Maori more injuries for plant and machinery workers (χ^2=810, df=4) and Pacific peoples more injuries for elementary occupations (χ^2=755, df=4) than other ethnic groups (see Table 35).

Total injury claims by gender and ethnicity

New Zealand Maori's recorded significantly more injury claims for both male (χ^2=2,939, df=4) and female (χ^2=202, df=4) than all other ethnic groups over the study period (see Table 36). When compared with the population distribution, New Zealand Maori males recorded 7% of the population distribution but recorded 39% of the injury claims and 33% of the injury entitlement costs. This was similar for New Zealand Maori females (pop: 7%; claims: 50%; costs: 47%); Pacific Island males (pop: 3%; claims 22%; costs 15%) and Pacific Island females (pop: 3%; claims: 18% costs 17%).

Table 35: Total injury claims by occupational group per 1000 entitlement claims, 95% Confidence Intervals and costs for ethnic groups from 1999 to 2007.

			New Zealand European				New Zealand Maori				Pacific Peoples				Asian				Other / Unknown			
Occupation	**P %[2]**	**RL %**	**No**	**Rate (95% CI)**	**%**	**$(000)**	**No**	**Rate (95% CI)**	**%**	**$(000)**	**No**	**Rate 95% CI)**	**%**	**$(000)**	**No**	**Rate (95% CI)**	**%**	**$(000)**	**No**	**Rate (95% CI)**	**%**	**$(000)**
Trades Workers	7.9	15.9	376	63.3 (57.2 to 70.0)	6.3	1,583	304	51.2 (45.7 to 57.3)	5.1	1,718	191	32.1 (27.9 to 37.0)	3.2	1,277	5	0.8 (0.4 to 2.0)	0.1	13	66	7.0 (5.5 to 8.9)	1.1	454
Plant & machinery	5.8	21.3	339	57.1 (51.3 to 63.)	5.7	3,957	589	99.1 (91.4 to 107.5)	9.9	2,671	240	40.4 (35.6 to 45.8)	4.0	1,216	0	0.0 -	0.0	0	98	10.4 (8.5 to 12.7)	1.6	521
Other[1]	5.7	16.5	319	53.7 (48.1 to 59.9)	5.4	1,379	356	59.9 (54.0 to 66.5)	6.0	6,269	198	33.3 (29.0 to 38.3)	3.3	1,456	10	1.7 (0.9 to 3.1)	0.2	39	100	10.6 (8.7 to 12.9)	1.7	659
Elementary[1]		19.6	275	46.3 (41.1 to 52.1)	4.6	1,553	560	94.3 (86.8 to 102.4)	9.4	4,197	242	40.7 (35.9 to 46.2)	4.1	2,137	7	1.2 (0.6 to 2.5)	0.1	32	81	8.6 (6.9 to 10.7)	1.4	1152
Sales & Service	9.4	5.4	125	21.0 (17.7 to 25.1)	2.1	686	99	16.7 (13.7 to 20.3)	1.7	501	75	12.6 (10.1 to 15.8)	1.3	291	3	0.2 (0.0 to 1.2)	0.0	1	21	2.2 (1.5 to 3.4)	0.4	87
Agriculture & Fisheries	11.0	4.9	91	15.3 (12.5 to 18.8)	1.5	573	141	23.7 (20.1 to 28.0)	2.4	711	40	6.7 (4.9 to 9.2)	0.7	196	0	0.0 -	0.0	0	21	2.2 (1.5 to 3.4)	0.4	118
Clerks	12.1	6.0	79	13.3 (10.7 to 16.6)	1.3	646	127	21.4 (18.0 to 25.4)	2.1	1,230	132	22.2 (18.7 to 26.4)	2.2	728	4	0.7 (0.3 to 1.8)	0.1	7	14	1.5 (0.9 to 2.5)	0.2	68
Technicians	12.2	5.0	103	17.3 (14.3 to 21.0)	1.7	663	88	14.8 (12.0 to 18.3)	1.5	535	93	15.7 (12.8 to 19.2)	1.6	413	3	0.3 (0.1 to 1.3)	0.0	5	10	1.1 (0.6 to 2.0)	0.2	132
Professionals	18.9	3.0	71	12.0 (9.5 to 15.1)	1.2	336	55	9.3 (7.1 to 12.1)	0.9	516	45	7.6 (5.7 to 10.1)	0.8	462	3	0.3 (0.1 to 1.3)	0.0	8	7	0.7 (0.4 to 1.6)	0.1	112
Legislators	17.1	2.3	61	10.3 (8.0 to 13.2)	1.0	365	46	7.7 (5.8 to 10.3)	0.8	263	24	4.0 (2.7 to 6.0)	0.4	132	3	0.3 (0.1 to 1.3)	0.0	4	6	0.6 (0.3 to 1.4)	0.1	60

CI: Confidence Interval; Rate reported per 1000 injury claims; P% = Percentage of population from Census 2006[1]; $(000) expressed in New Zealand Dollars; Total do not equal due to data rounding. 1= Employment category combined under Statistics NZ classifications; 2= percentages reported from 2006 Census; RL% = Total percentage of total injury claims by occupational group. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 36: Total injury claims by ethnic groups with 95% Confidence intervals and percentages of total claims from 1999 to 2007. Total population by ethnic group and percentage of population, injury costs, percentage of injury costs and mean cost per claim by ethnic group from 1999 to 2007.

		Total Population		Injury Claims			Injury entitlement costs		
		No.	%	No	Rate (95% CI)	%	$(000)	%	Mean $
Male	New Zealand European	1,255,257	31.2	1764	313.7 (299.4 to 328.7)	31.4	9,185	22.3	5,207
	New Zealand Maori	274,860	6.8	2205	392.1 (376.1 to 408.9)	39.2	13,526	32.8	6,134
	Pacific Peoples	131,007	3.3	1224	217.7 (205.8 to 230.2)	21.8	6,315	15.3	5,159
	Asian	169,374	4.2	33	5.9 (4.2 to 8.3)	0.6	86	0.2	2,598
	Other/Unknown	304,497	7.6	377	67 (60.6 to 74.2)	6.7	2,257	5.5	5,984
Female	New Zealand European	1,354,332	33.6	75	234.4 (186.9 to 293.9)	23.4	355	22.5	4,722
	New Zealand Maori	290,466	7.2	160	500.0 (428.2 to 583.8)	50.0	746	47.4	4,659
	Pacific Peoples	134,967	3.4	56	175.0 (134.7 to 227.4)	17.5	262	16.6	4,673
	Asian	185,175	4.6	0	0.0 -	0.0	-	0.0	-
	Other/Unknown	282,564	7.0	47	146.9 (110.4 to 195.5)	14.7	211	13.4	4,486

Rates are per 1000 injury claims; CI: Confidence Intervals; $(000) expressed in New Zealand Dollars; Population numbers from 2006 census. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Discussion

This study identified the number of injury claims, and associated costs, by ethnic group that have occurred from participation in rugby league activities in New Zealand over an eight year period. There have been no studies looking at ethnicity and injuries in rugby league. Despite this there has been some ethnographic research exploring ethnic rugby league players at the professional level of participation in the Northern hemisphere.[228] Seen as a development of personal and social self, ethnic players reportedly participate in contact sports such as rugby league because of the physicality of the game and the ability to be aggressive in a controlled way.[228] Participation in sport by ethnic groups has been described as a positive experience for the players where sports skills are encouraged, and rewarded, amongst their peers, and the wider community, as well as enabling bonding with the players *"whanau, hapu, iwi and friends"*.[247] It is one area where players can demonstrate their masculinity and prowess to both other males and to females.[228] This participation has also been described as an area where a player's identity is tied up with the mythologies that some see rugby league as achieving (working class solidarity) and being able to "*achieve success and play with pakeha as equals."*[59]

When compared to the percentage proportion of population, New Zealand Maori are over-represented in many sporting codes.[247] It has been previously reported that 42% of rugby league participants are New Zealand Maori, 32% European, 22% Pacific and 4% are of other ethnic groups.[59] No current rugby league participation data were available for the period of our study to use as a comparison. The results of our study identified that 40% of the total injury claims were recorded as being New Zealand Maori, 29% New Zealand European, 19% Pacific People and 8% other ethnicity. The percentages varied by island and district. The North Island recorded more New Zealand Maori injury claims while the South Island recorded more New Zealand European injury claims. Auckland recorded more Pacific Peoples injury claims (13%) despite Pacific Peoples only accounting for 5% of the total population in Auckland. There were more New Zealand Maori injury claims in Northland and from Waikato through to Tasman than New Zealand Europeans' claims. New Zealand Europeans recorded more injury claims from Nelson through to Southland than New Zealand Maori. Further research is warranted in identifying whether the ethnic distribution difference as observed in this study for injury claims is also evident in participation numbers.

The incidence of injury claims decreased each year for New Zealand European and New Zealand Maori. In contrast, Pacific Peoples and Asians recorded an increase in the incidence of injury claims over the same reporting period. As reported in another epidemiological study,[157] the incidence of injury claims initially decreased over the 1999-2000 to 2001-02 reporting periods then increased by 26% ±20% over the 2002-06 reporting period. It is not known whether the actual participation numbers varied across the study period or if there were other influences over the same reporting period. The implementation of a national rugby league participation database would assist in identifying any changes in ethnic groups and player numbers for future research.

The finding that soft tissue injuries were recorded as the most common injury type for most ethnic groups reflects the nature of the game of rugby league.[78] Soft tissue injuries (sprains, strains, contusions and haematomas) accounted for 46% ±4% of total injury types recorded for all ethnic groups. This was similar for fracture dislocations recording 45%, ±3% of the total injury types. Combined, these injury types accounted for 77% ±20% injury entitlement costs for all ethnic groups. This is reflective of the nature of rugby league where tackling, being tackled, acceleration, deceleration and change of direction are key components of rugby league at all levels of participation.[72] Studies reporting injuries in rugby league have identified that these injury types are the most common to occur at all levels of participation.[159] As these injury types are similar between all ethnic groups, injury prevention / reduction programs should be generalisable for all ethnic groups. This would include primary care of these types of injuries through appropriate sideline care by qualified personnel. Further longitudinal research is warranted once these programs are commenced to see what impact on the incidence of injury claims the programs have.

The finding that the lower limb was the most common injury entitlement region may be reflective of the ethnic group differences. Recent research on foot function and morphology of different ethnic groups in rugby league has shown that there are functional differences in foot loading and morphology during gait for different ethnicities.[126] New Zealand Maori and New Zealand Europeans were reported to have a narrower hallux angle and a wider forefoot in regards to total area of the foot in comparison to Pacific Peoples. As shown by this study more injury claims were recorded for the lower limb by New Zealand Maori (17%) and New Zealand Europeans (16%) than Pacific Peoples (10%) and Asians (1%). Although no relationship has been proven between the different ethnic group’s foot morphology and the incidence of injuries, research is warranted on ascertaining if there is a correlation. Other aspects to be considered are whether there are different stressors on the ankle and knee joints of different ethnicities and how this relates to participation in contact sports such as rugby league.

The incidence and costs of concussions is a concern. King et al.[157] identified that the mean cost of a concussion over the same reporting period was $25,347 (£9,487). The mean cost per concussion over the duration of this study varied by ethnic group. New Zealand European's recorded the lowest mean cost of $2,113 (£803) per concussion while New Zealand Maori recorded the highest mean cost per concussion of $38,118 (£14,488). Explanation of this is beyond the scope of this study but questions raised by this finding are: (1) Is there a reason for the difference in costs associated with concussions by different ethnic groups?; and (2) Do New Zealand Maori have an increased risk of complications from concussions when compared with New Zealand Europeans and Pacific Peoples? The reason for the mean high cost per concussion, and in particular for New Zealand Maori, are areas that warrant further investigation. Comparison between other ethnic groups, outside of those identified in this study, may also be warranted to further explore the area of concussion by ethnicity.

The ethnic groups reported in the ACC data base are limited and data interpretation may influence what ethnic group the injury entitlement claim will be entered in as, especially if two ethnic groups are selected (i.e. New Zealand Maori and New Zealand European). Another limitation in the use of this data is the occupational classification identified. The occupational classifications provided are limited to just ten classifications as identified by the New Zealand Standard Classifications of Occupations.[128] Although there are sub classifications under this standard, these are not recorded in the data input process. The data interpretation of the occupational classification is open for interpretation at the data input stage by the data input operator i.e. a program manager can be classified as professional, technical or administrator whereas they may be a program manager for a trade worker, a computer operator or an elementary occupation.

Despite the limitations of occupational classifications, the current study is similar to another study[125] that reported occupational classification of participants in rugby league. Greenwood[125] identified the small number of 'white-collar' workers and a greater combination of skilled and unskilled workers participating in rugby league activities. Plant and machine operators and assemblers (21%), elementary occupations (19%) and trade workers (17%) were the most commonly reported occupational groups of participants in our study. Professionals, legislators, administrators, managers, technicians and associate professionals recorded only 12% of the total injury claims over the study period. This would suggest, similar to Greenwood,[125] that rugby league participation is primarily undertaken by the 'blue collar' class of occupations in the employment sector.

Conclusions

Although this study was unable to establish the injury incidence per 1000 match hours for ethnic groups, it has identified that there are some differences in the injury site and injury type between different ethnic groups. The costs associated with the different ethnic groups as a result of injuries from rugby league participation were identified. Further research is warranted to fully explore the differences between the ethnic groups and what extent these differences are from participation in rugby league activities. Further questions raised by this study are: (1) Despite an increase in the total injury incidence over the period why is there a decrease in injury claims for New Zealand Europeans and New Zealand Maori but an increase in injury claims for Pacific Peoples and Asians?; (2) Are there anthropometric and physiological aspects of different ethnic groups that impact on the incidence of injuries in rugby league participants?

CHAPTER 6: WOMEN'S RUGBY LEAGUE INJURY CLAIMS AND COSTS IN NEW ZEALAND

This chapter comprises the following paper accepted by the *British Journal of Sports Medicine.*

Reference

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Author contributions

King, D. 70%; Hume, P. 15%; Milburn, P. 10%; Gianotti, S. 5%

Overview

There is scarce information on rugby league injuries in female players. This study provides an overview of the epidemiology of women's rugby league injuries requiring medical treatment and associated costs in New Zealand. New Zealand Accident Compensation Corporation injury data for the period 1999 to 2007 were searched for rugby league injury cases occurring in females. Data were analysed by demographics, body region, nature/severity of injury, and medical procedure and costs. There were 320 moderate to serious (MSC) injury claims recorded for females participating in rugby league activities over the study period. There was a mean ±SD of 38, ±10 injury claims per year. The mean cost per year for the study period was $196,514, ±$99,133 [£76,066, ±£38,374] with half of the injury claims occurring in New Zealand Maori. Concussion / brain injuries accounted for 4% of total female MSC injury claims but accounted for 5% of female injury costs ($84,399 [£32,688]) with the highest mean cost per claim ($7,033 [£2,724]). The lower limb accounted for 65% of the total female injury claims and 59% of total injury costs ($922,296 [£356,968]). The mean cost per claim was higher for the lower limb ($4,434 [£1,714]) than the upper ($3,331 [£1,288]) limb. Clerks recorded 16% of the total injury claims, 20% of total injury costs ($319,474 [£123,211]) and had the highest mean cost per claim ($6,144 [£2,370]). The 25-29 age group recorded 32% of injury claims and 34% of injury costs. The 35-39 age group recorded the highest mean cost per claim ($6,200 [£2,392]) but only 11% of total claims and 14% of total costs. When compared with other studies in rugby league injuries, it appears that females incur substantially fewer injuries (6%) than males (94%). Though no participation data by gender are available, it is likely that participation percentages are reflected in the injury percentages. The high frequency (65%) and cost proportion (59%) for lower limb injuries was higher in females than in male rugby league players (previously reported as 42% of the injury claims and 32% of the total injury claim costs for the lower limb). Injury prevention

programs for women's rugby league should focus on the 25-29 age group and address ways to prevent concussion and lower limb injuries.

Introduction

Beginning from the it's early origins in the north of England in the 1890's,[87] the game of rugby league has become an internationally participated collision sport[73, 78, 87] played at elite, semi-elite, amateur and junior levels.[69, 73, 87] Rugby league requires the participants to undergo repetitive physical collisions and tackles.[154, 223, 230] During an 80 minute game, the ball is in play for an average of 50 minutes,[137] with each player being involved in between 20 to 40 tackles per game[137] and covering between 7000 to 10000 metres.[181] As a result of these physical collisions, musculoskeletal injuries occur frequently.[69, 78, 154]

Although the most common rugby league participant is male, female participation in rugby league does occur.[91] The first recorded women's rugby league match was played in Sydney, Australia on the 17th September 1921.[167] It was described as a "freak show", as it was seen to be a threat to the masculine underpinnings of the game, but 25000 people were reported to watch the match between the established Sydney and Metropolitan teams.[167] Yet despite positive reports about the spectacle of women's rugby league, players were ridiculed and attempts to establish the game were sporadic and often floundered.[167] It was not until 1990's that women's rugby league became firmly established international amateur participation sport.[167]

Studies have demonstrated the nature and incidence of injuries in rugby league when played by males[69, 73, 78, 87, 137, 154, 223, 230] and that the incidence of injury typically increases as the participation level increases. The rugby league injury rates vary for senior (amateur, semi-elite, elite)[69, 73, 87] and junior[92, 213] participants with elite players typically having a higher injury incidence in most,[78, 87] but not all,[77] published studies. When reporting injuries resulting in missed matches only, the rate varies from 26.8[72] to 67.7[77] per 1000 playing hours but when considering all injuries (including transient injuries), the incidence varies from 58.4[246] to 824.7[77] per 1000 playing hours depending on the injury definition utilised.[155]

However, there is a paucity of data to indicate the nature of injuries sustained by females playing rugby league, with a review of the literature showing only two published studies.[91, 150] One study[91] reviewed the anthropometric and physiological perspectives of elite women's rugby league participants, while the other reported the incidence of injuries at a women's rugby league tournament.[150] No other studies appear to have been published on women's rugby league despite there being domestic, national and international competitions played.

An epidemiological overview of rugby league injuries and the associated injury costs has previously been undertaken.[157] This study combined both male and female injury claims but did not differentiate them in its analysis. This current paper builds on the initial work by providing further analysis of the women's injury data with the aim of enhancing understanding of injuries that occur in women's rugby league to help develop injury reduction programs specifically targeted at female participants. With this mind, the goal of this paper was to provide an epidemiological overview of female rugby league injuries in one country (New Zealand) over eight years. New Zealand's no-fault injury compensation system administered by the Accident Compensation Corporation (ACC) means that New Zealand is uniquely positioned to provide detailed descriptive epidemiological data including costs associated with treatment on female rugby league participants. Using these data, a comparison of the rate, site, type, occupation, age and location of female rugby league injuries was conducted.

Methods

ACC cover is available to any person, including visitors to New Zealand that suffer any accidental personal injury at any time when in New Zealand. People who have a personal injury can make a claim to ACC at the time of seeking medical treatment from over 30000 registered health professionals throughout the country. When making a claim, information about the injury is collected using a standard ACC 45 injury reporting form to ensure levels of consistency for data recording and analyses. The injured person (unless impaired) completes information about the activity surrounding the injury (e.g., location, activity prior, cause, narrative) along with their personal details (e.g., age, gender, ethnicity, contact details). The registered health professional completes the form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and details are entered into a central database.

ACC has no disincentive for making claims nor are people risk-rated or penalised for the number of claims they make.[111] Personal injury coverage is guaranteed by ACC but this is offset by the restriction to sue for personal injury except in rare circumstances for exemplary damages.[111] ACC categorises the claims made as minor or moderate to serious claims (MSC) and as new or ongoing injury claims. Minor injury claims reflect those injuries that require the initial medical treatment or service and may only require one or two visits to a health professional. Moderate to serious injury claims reflect those injuries that require additional treatment than the initial medical treatment or service, for example income replacement if the injury requires more than five consecutive days off work. Serious injury claims are permanent brain injury or spinal damage. New claims are those made in the reporting period and are reflective of the number of new injuries from rugby league participation. Ongoing injury claims are reflective of the severity of the injury claim and can carry on over the reporting period. In this study MSC's are reported with new and ongoing injuries combined per reporting period.

Throughout the study period there were 42754 rugby league claims costing the ACC $ 48,704,704 [£18,099,470]. Female MSC represented only 0.7% (320) of the number of total rugby league claims and 3% ($1,572,110 [£614,787]) of the total rugby league injury entitlement costs. For this review we focused on MSC rather than minor rugby league claims as defined by the ACC for its sports cost outcome model,[111] that occurred between 1st July 1999 and the 30th June 2007 as a result of participating in rugby league activities.

As there were no reliable rugby league participation data collected by New Zealand Rugby League, New Zealand population data were obtained from official government sources. This data set provides estimates of resident populations between each five year census.[1] The population of New Zealand over the study period was approximately 4.1 million people based on the 2006 census[1] and the proportion of females in the population in 2006 was 51.2% (2.1 million). ACC data were analysed by various categories: (1) Injury site; (2) Injury type; (3) Age; (4) Region/District and Occupational classification[128] (see Table 37).

Table 37: Data categories analysed.

Ethnicity		Region		Injury site		Injury type	Age	Occupation
Group	includes	Area	District	Group	Sub-group		in years	NZSCO categories[128]
New Zealand European		**North Island**		**Head/Neck**		Soft tissue injury	5 - 9	Legislators, Administrators, and Managers
New Zealand Maori			Northland		Head (except face)	Corrosive injuries	10 - 14	Professionals
Pacific Peoples			Auckland		Face	Dental injuries	15 - 19	Technicians and Associate Professionals
	Cook Island Maori		Waikato		Eye	Fracture / Dislocation	20 - 24	Clerks
	Tongan		Bay of Plenty		Nose	Hernia	25 - 29	Service and Sales Workers
	Niuean		Gisborne		Ear	Laceration, puncture, wound, sting	30 - 34	Agriculture and Fishery Workers
	Fijian		Hawke's Bay		Neck / Back of head / vertebrae	Foreign body in orifice / eye	35 - 39	Trades Workers
	Tokelauan		Taranaki	**Upper Limb**		Concussion / brain injury	40 - 44	Plant and Machine Operators and Assemblers
	Other Pacific		Manaweatu-Wanganui		Shoulder (including Clavicle/Shoulder blade)	Amputation	45 - 49	Elementary Occupations
Asian			Wellington		Upper and Lower Arm	Deafness	50 - 54	Unknown
	South East Asian	**South Island**			Elbow	Other / Unknown	55 - 59	
	Indian		Tasman		Hand / wrist		60 - 64	
Other/Unknown			Nelson		Finger / Thumb		65 - 69	
			Marlborough	**Lower Limb**			70 - 79	
			Canterbury		Hip/Upper leg/Thigh		80 +	
			West Coast		Knee			
			Otago		Lower Limb			
			Southland		Ankle			
		Other/Unknown			Foot			
					Toes			
				Chest / Back / Other				
					Abdomen / Pelvis			
					Chest			
					Back / Spine			
					Internal organ			
					Multiple locations			
				Unknown				

Ethical consent

Ethical consent for the research was obtained from the Auckland University of Technology Ethics Committee. Informed consent from the injured participants was not obtained as data were collected from the ACC data base without individual player follow-up.

Data limitations

Epidemiological studies are dependant on data quality for any analysis to be undertaken.[112] The data provided for the analysis in this study is from the ACC database and is dependant on several factors: (1) The correct data code was on the data collection sheet; (2) The occupational classifications provided are limited to just ten classifications as identified by the New Zealand Standard Classifications of Occupations.[128] Although there are sub classifications under this standard, these are not recorded in the data input process. (3) The occupational classification is open for interpretation by the data operator at the data input stage i.e. a program manager can be classified as a professional, technical or administrator where as they may be a program manager for a trade worker, computer operator or elementary occupation. (4) People going to a registered health professional for treatment of their injury; (5) Underreporting of costs due to patients undertaking private medical care; and (6) People making a claim for the injury (there is no time limit on when a patient can make an acute injury claim to ACC).[112] The data retrieved is protected to ensure client confidentiality by limiting the access to low level results under four injury claims. Therefore any data less than or equal to three injury claims has been rounded to represent three claims only. The net result of these limitations may see a downwards bias in the injury entitlement claim incidence and, some of the calculations will not be equal depending upon the way the data was rounded.

Statistical analyses

All the data collected were entered into a Microsoft Excel spreadsheet and analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of injuries per 1000 rugby league injury claims.[135] Data are reported as means and standard deviations and with 95% confidence intervals (CI) where appropriate.[240] The injury rates and patterns were compared between reporting years using a one sample chi-squared (χ^2) test. Significant p values reported in the text are <0.001 if they are not specifically stated. Injury incidence was not calculated for the study as rugby league participation rates were not available as part of the data analysis. All costs are reported in New Zealand Dollars ($) and United Kingdom Pounds (£) unless otherwise indicated.

Results

Over the period July 1999 to June 2007 there were 320 MSC injury claims recorded for females participating in rugby league activities. The mean cost per MSC injury claim was $4,913 (£1872] from a mean, ±SD of 38, ±10 injury claims per year. The mean cost per year for the study period was $196,514, ±$99,133 [£76,066, ±£38,374]. Initially the injury claims and costs decreased (claims: 11%, ±3%; costs 9%, ±3%) per year over the 1999-2000 to 2001-02 reporting periods, but over the 2002-03 to 2006-07 reporting periods both the number and costs of injury claims increased (claims: 14%, ±3%; costs: 15%, ±7%) per year. There were no statistically significant differences observed in the decrease from 1999-2000 (137 per 1000 injury claims) to the 2001-02 (81 per 1000 injury claims) reporting years (see Table 38). However there was a significant increase in the injury claims in 2006-07 (171 per 1000 injury claims) compared to 2002-03 (100 per 1000 injury claims).

Female injury claims and costs by ethnic group

Half of the female injury claims were recorded as being to New Zealand Maori (500 per 1000 injury claims; 50%). New Zealand Maori also recorded nearly half of the injury costs ($745,497 [£288,605]; 47%) (see Table 39). There were significant differences observed between most, but not all, ethnic groups for the females over the study period although there were no recorded female Asians participating in rugby league throughout the study period.

Table 38: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences by reporting year. Total injury costs, percentage of total costs and mean cost per claim by reporting year.

	Total Female Injury Claims			Total Female Injury Costs			Difference from previous year for total injury claims		Difference from 99-00 for total injury claims		Difference from 02-03 for total injury claims	
Years	**No.**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=1), p value**		**χ^2 (df=1), p value**		**χ^2 (df=1), p value**	
99-00	44	137.5 (102.3 to 184.8)	13.8	184	11.7	4,179	-		-		1	0.169
00-01	33	103.1 (73.3 to 145.1)	10.3	123	7.8	3,714	1	0.210	1	0.210	0.0	0.901
01-02	26	81.3 (55.3 to 119.3)	8.1	96	6.1	3,681	4	0.031	0.8	0.362	0.6	0.431
02-03	32	100.0 (70.7 to 141.4)	10.0	122	7.7	3,796	1	0.169	0.6	0.431	-	
03-04	35	109.4 (78.5 to 152.3)	10.9	181	11.5	5,167	1	0.311	0.1	0.714	0.1	0.714
04-05	55	171.9 (132.0 to 223.9)	17.2	276	17.5	5,014	1	0.269	4	0.035	6	0.014
05-06	40	125.0 (91.7 to 170.4)	12.5	193	12.3	4,833	0.2	0.663	2	0.124	0.8	0.346
06-07	55	171.9 (132.0 to 223.9)	17.2	399	25.4	7,247	1	0.269	2	0.124	6	0.014

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 39: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by ethnicity 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by ethnic group 1999 to 2007.

	Total Female Injury Claims			Total Female Injury Costs			Difference from NZ European for total injury claims		Difference from NZ Maori for total injury claims		Difference from Pacific Peoples for total injury claims		Difference from Asian for total injury claims		Difference from Other / Unknown for total injury claims	
Ethnic Group	**No**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean$**	**χ^2 (df=1)**	**p value**	**χ^2 (df=1)**	**p value**	**χ^2 (df=1)**	**p value**	**χ^2 (df=1)**	**p value**	**χ^2 (df=1)**	**p value**
New Zealand European	70	218.8 (173.1 to 276.5)	21.9	354	22.5	5,059										
New Zealand Maori	160	500.0 (428.2 to 583.8)	50.0	746	47.4	4,659	30	<0.001								
Pacific Peoples	51	159.4 (121.1 to 209.7)	15.9	262	16.6	5,131	2	0.097	50	<0.001						
Asian	0	0.0 -	0.0	-	0.0	-	75	<0.001	160	<0.001	56	<0.001				
Other/Unknown	39	121.9 (89.0 to 166.8)	12.2	211	13.4	5,406	6	0.011	61	<0.001	0.7	0.375	47	<0.001		

Rates are per 1000 injury claims. CI: Confidence Interval. Percentage totals do not to 100% add due to rounding. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 40: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by district 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by district 1999 to 2007.

	Total Female Injury Claims			**Total Female Injury Costs**			Difference over reporting years for total injury claims		Difference 99-00 and 06-07 for total injury claims		Difference from Auckland for total injury claims	
	No	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**		**χ^2 (df=1), p value**	
North Island Total	**244**	**762.5 (672.6 to 864.4)**	**76.3**	**1,215**	**77.3**	**4,978**	**12**	**0.0769**	**0.9**	**0.3346**	**-**	
Northland	19	59.4 (37.9 to 93.1)	5.9	38	2.4	2,005	16	0.019	0	1.0	104	<0.001
Auckland	153	478.1 (408.1 to 560.2)	47.8	854	54.3	5,585	12	0.098	0.6	0.405	-	
Waikato	17	53.1 (85.1 to 100.6)	9.3	4,263	10.0	7,750	4	0.689	0.5	0.480	92	<0.001
Bay of Plenty	20	62.5 (40.3 to 96.9)	6.3	91	5.8	4,562	2	0.925	0.1	0.706	82	<0.001
Gisborne	6	18.8 (8.4 to 41.7)	1.9	30	1.9	5,033	9	0.253	3	0.083	113	<0.001
Hawkes' Bay	8	25.0 (12.5 to 50.0)	2.5	71	4.5	8,902	10	0.189	0	1.0	111	<0.001
Taranaki	7	21.9 (10.4 to 45.9)	2.2	5	0.3	690	9	0.253	3	0.083	113	<0.001
Manawatu-Wanganui	4	12.5 (4.7 to 33.3)	1.3	26	1.6	6,462	15	0.036	3	0.083	128	<0.001
Wellington	10	31.3 (16.8 to 58.1)	3.1	30	1.9	3,001	8	0.333	5	0.025	0.2	<0.001
	Total Female Injury Claims			**Total Female Injury Costs**			Difference over reporting years for total injury claims		Difference 99-00 and 06-07 for total injury claims		Difference from Canterbury for total injury claims	
	No	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**		**χ^2 (df=1), p value**	
South Island Total	**64**	**200.0 (156.5 to 255.5)**	**20.0**	**336**	**21.4**	**5,254**	**7**	**0.3741**	**1**	**0.2207**	**-**	
Tasman	0	0.0 -	0.0	-	0.0	-	0	1.0	0	1.0	49	<0.001
Nelson	3	9.4 (3.0 to 29.1)	0.9	18	1.2	6,097	6	0.509	0	1.0	27	<0.001
Marlborough	3	9.4 (3.0 to 29.1)	0.9	>1	0.0	258	21	0.004	3	0.083	40	<0.001
Canterbury	49	153.1 (115.7 to 202.6)	15.3	305	19.4	6,227	4	0.734	0.6	0.439	-	
West Coast	3	9.4 (3.0 to 29.1)	0.9	6	0.4	2,091	18	0.012	3	0.083	33	<0.001
Otago	6	18.8 (8.4 to 41.7)	1.9	6	0.4	959	18	0.012	3	0.083	33	<0.001
Southland	0	0.0 -	0.0	-	0.0	-	0	1.0	0	1.0	49	<0.001
	Total Female Injury Claims			**Total Female Injury Costs**			Difference over reporting years for total injury claims		Difference 99-00 and 06-07 for total injury claims			
Other / Unknown	**No**	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**			
Other/Unknown Total	**12**	**37.5 (21.3 to 66.0)**	**3.8**	**21**	**1.4**	**1,778**	**12**	**0.101**	**0**	**1.0**		

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Female injury claims and costs by district

For female rugby league players, more injury claims were recorded in the North (943 per 1000 injury claims; 94%) than the South Island (228 per 1000 injury claims; 23%) (χ^2=139, df=1) (see Table 40). Over three-quarters of the costs were for North Island based players ($1,214,543 [£470,373]; 77%). Despite this, the highest mean cost per injury entitlement claim was recorded in the South Island ($4,606 [£1,784] vs. $4,022 [£1,557]). In the North island, the major metropolitan region of Auckland recorded more claims (478 per 1000 injury claims, 48%) and costs ($854,438 [£330,864]) than other North Island districts (χ^2=501, df=8). In the South Island, Canterbury recorded more claims (153 per 1000 injury claims, 15%) and costs ($305,142 [£118,160]) than other South Island districts (χ^2=156, df=6). Canterbury also recorded the highest mean cost per injury claims ($6,227 [£2,412]).

Female injury claims and costs by injury type

Soft tissue injuries were the most commonly claimed injury while fracture-dislocations were slightly less (see Table 41). Concussion / brain injuries accounted for 4% of total female MSC injury claims but accounted for 5% of costs ($84,399 [£32,688]) and the highest mean cost per claim ($7,033 [£2,724]).

Female injury claims and costs by injury site

There were differences between the total number of injury claims for injuries to the head and neck (χ^2=10, df=5, p=0.075), upper limbs (χ^2=24, df=4), lower limbs (χ^2=237, df=5) and chest and back (χ^2=41, df=4) for female rugby league players and these were significant. There was also a two-fold increase in injury risk for the lower limb when compared with the upper limb (RR: 1.9; 95% CI: 1.6 to 2.3) while the head and neck (RR: 3.9; 3.0 to 5.0) and chest, back and other (RR: 7.7; 5.3 to 11.3) had an even higher risk of injury. The knee was the most commonly recorded injury site followed by the ankle; shoulder and lower leg (see Table 42). The lower limb recorded 65% of the total female injury claims and 59% of total injury entitlement costs ($922,296 [£356,968]). The mean cost per injury entitlement claim was higher for the lower ($4,434 [£1,714]) than the upper ($3,331 [£1,288]) limb. The highest injury site mean cost per injury entitlement claim was recorded for the head (except face) ($7,033 [£2,724]) while the shoulder, ($5,746 [£2,223]) knee ($5,568 [£2,154]) and ankle ($4,317 [£1,670]) were less.

Female injury claims and costs by occupational group

There were significant differences in the number of injury claims recorded for all occupational groups (χ^2=107, df=8) (see Table 43). Although female clerks are reported as comprising 10% of the total workforce, they recorded 16% of the total injury claims (162 per 1000 injury claims), 20% of total injury costs ($319,474 [£123,211]) and had the highest mean cost per claim ($6,144 [£2,370]) (see Table 7). Sales and service workers (workforce: 9%; claims: 13%; costs 11%), technicians and associate professionals (workforce: 6% claims: 13%; costs: 11%) and plant and machinery operators and assemblers (workforce: 2%; claims 11%; costs: 12%) recorded less.

Female injury claims and costs by age

The 25-29 age group recorded 32% of injury claims and 34% of injury costs (see Table 44). This was significantly more than the 20-24 age group (claims: 21%; costs: 16%; χ^2=6, df=1) and the 30-34 age group (claims: 21%; costs: 25%; χ^2=7, df=1, p=0.007). The 35-39 age group recorded the highest mean cost per claim ($6,200 [£2,392]) but only 11% of total injury claims and 14% of total costs.

Table 41: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by injury type from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by injury type from 1999 to 2007.

	Total Female Injury Claims			Total Female Injury Costs			Difference over reporting years for total injury claims		Difference between 99-00 and 06-07 for total injury claims	
	No	**Rate (95% CI)**	**%**	**$(000)**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**	
Soft Tissue Injuries	171	534.4 (460.0 to 620.8)	53.4	848	53.9	4,960	13	0.070	1	0.267
Fracture / Dislocations	118	368.8 (307.9 to 441.7)	36.9	500	31.8	4,237	7	0.360	0.1	0.746
Other / Unknown	20	62.5 (40.3 to 96.9)	6.3	112	7.1	5,587	9	0.197	3	0.083
Concussion / Brain Injury	4	12.5 (4.7 to 33.3)	1.3	84	5.4	21,100	12	0.101	0	1.0
Lacerations / Puncture / Wounds	4	12.5 (4.7 to 33.3)	1.3	25	1.6	6,221	12	0.101	0	1.0
Deafness	3	9.4 (3.0 to 29.1)	0.9	3	0.2	993	21	0.004	0	1.0
Dental Injuries	0	0.0 -	0.0	-	0.0	-	-		-	
Foreign body in orifice / eye	0	0.0 -	0.0	-	0.0	-	-		-	

CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 42: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by gender and injury site from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by gender and injury site from 1999 to 2007.

	Total Female Injury Claims			Total Female Injury Costs			Difference over reporting years		Difference 99-00 and 06-07	
	No.	Rate (95% CI)	%	$(000)	%	Mean $	χ^2 (df=7), p value		χ^2 (df=1), p value	
Head & Neck	**23**	**71.9 (47.8 to 108.2)**	**7.2**	**155**	**9.9**	**6,743**	**36**	**<0.001**	**1**	**0.273**
Head (except face)	4	12.5 (4.7 to 33.3)	1.3	84	5.4	21,100	12	0.101	0	1.0
Neck, Back of head	8	25.0 (12.5 to 50.0)	2.5	34	2.1	4,206	9	0.253	0	1.0
Face	2	6.3 (1.6 to 25.0)	0.6	3	0.2	1,338	18	0.012	0	1.0
Eye	3	9.4 (3.0 to 29.1)	0.9	13	0.8	4,355	15	0.036	0	1.0
Ear	3	9.4 (3.0 to 29.1)	0.9	20	1.3	6,729	15	0.036	3	0.083
Nose	3	9.4 (3.0 to 29.1)	0.9	1	0.1	374	21	0.004	3	0.083
Upper Limb	**71**	**221.9 (175.8 to 280.0)**	**22.2**	**356**	**22.7**	**5,020**	**8**	**0.327**	**0.0**	**0.862**
Shoulder	39	121.9 (89.0 to 166.8)	12.2	230	14.6	5,894	3	0.843	0.1	0.763
Upper & Lower Arm	14	43.8 (25.9 to 73.9)	4.4	47	3.0	3,330	3	0.885	0	1.0
Elbow	3	9.4 (3.0 to 29.1)	0.9	7	0.4	2,313	15	0.036	3	0.083
Hand/wrist	6	18.8 (8.4 to 41.7)	1.9	40	2.5	6,673	6	0.570	0	1.0
Finger/Thumb	9	28.1 (14.6 to 54.1)	2.8	33	2.1	3,663	6	0.463	0.1	0.706
Lower Limb	**194**	**606.3 (526.7 to 697.9)**	**60.6**	**922**	**58.7**	**4,754**	**13**	**0.062**	**0.5**	**0.446**
Hip, Upper leg, Thigh	2	6.3 (1.6 to 25.0)	0.6	16	1.0	7,825	18	0.012	0	1.0
Knee	109	340.6 (282.3 to 411.0)	34.1	607	38.6	5,568	7	0.367	0.7	0.398
Lower Leg	16	50.0 (30.6 to 81.6)	5.0	66	4.2	4,116	4	0.780	0	1.0
Ankle	49	153.1 (115.7 to 202.6)	15.3	220	14.0	4,493	5	0.584	1	0.248
Foot	15	46.9 (28.3 to 77.8)	4.7	14	0.9	905	9	0.253	0	1.0
Toes	3	9.4 (3.0 to 29.1)	0.9	<0.5	0.0	57	21	0.004	3	0.083
Chest, Back, Other	**9**	**28.1 (14.6 to 54.1)**	**2.8**	**29**	**1.9**	**3,238**	**18**	**0.011**	**0**	**1.0**
Chest	4	12.5 (4.7 to 33.3)	1.3	3	0.2	740	12	0.101	0	1.0
Back/Spine	5	15.6 (6.5 to 37.5)	1.6	26	1.7	5,236	9	0.253	0	1.0
Abdomen/Pelvis	0	0.0 -	0.0	-	0.0	-		-		-
Internal organs	0	0.0 -	0.0	-	0.0	-		-		-
Multiple Injuries	0	0.0 -	0.0	-	0.0	-		-		-
Unknown	**22**	**68.8 (45.3 to 104.4)**	**6.9**	**109**	**6.9**	**4,962**	**0.2**	**0.999**	**0**	**1.0**

CI: Confidence Interval. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 43: Percentage of total female population by occupational group and by total workforce. Total injury rates per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by occupational group from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by occupational group from 1999 to 2007.

	Females by Consensus[1]		**Total Female Injury Claims**			**Total Female Injury Costs**			**Difference over reporting years**		**Difference over 99-00 and 06-07**	
	% occupation	**% workforce**	**No**	**Rate (95% CI)**	**%**	**$0**	**%**	**Mean $**	**χ^2 (df=7), p value**		**χ^2 (df=1), p value**	
Unknown	4.3	0.2	84	262.5 (212.0 to 325.1)	26.3	363	23.1	4,321	7	0.386	1	0.178
Clerks	78.2	9.8	52	162.5 (123.8 to 213.3)	16.3	319	20.3	6,144	1	0.968	0	1
Technicians and Associate Professionals	51.6	5.7	39	121.9 (89.0 to 166.8)	12.2	171	10.9	4,378	7	0.409	0	1
Service and Sales Workers	64.6	9.1	37	115.6 (83.8 to 159.6)	11.6	165	10.5	4,453	4	0.684	0.4	0.527
Plant and Machine Operators and Assemblers	20.4	1.7	31	96.9 (68.1 to 137.8)	9.7	194	12.3	6,242	3	0.821	1	0.317
Elementary Occupations	39.4	2.3	30	93.8 (65.5 to 134.1)	9.4	124	7.9	4,127	4	0.712	0.1	0.763
Legislators, Administrators and Managers	39.5	5.0	18	56.3 (35.4 to 89.3)	5.6	94	6	5,218	0.2	0.999	0	1
Professionals	55.7	7.7	13	40.6 (23.6 to 70.0)	4.1	62	3.9	4,760	11	0.111	0	1
Trades Workers	5.8	0.5	10	31.3 (16.8 to 58.1)	3.1	68	4.3	6,826	18	0.012	3	0.083

CI: Confidence Interval. Rates are per 1000 injury claims. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Table 44: Total injury rate per 1000 entitlement claims with 95% Confidence Intervals and percentage of total claims and differences per year by age from 1999 to 2007. Total injury costs, percentage of total costs and mean cost per claim by age from 1999 to 2007.

Age	Total Female Injury Claims			Total Female Injury Costs			Difference over reporting years		Difference 99-00 and 06-07	
	No	Rate (95% CI)	%	$(000)	%	Mean $	χ^2 (df=7), p value		χ^2 (df=1), p value	
5 - 9	0	0.0 -	0.0		0.0	-	-		-	
10-14	9	9.4 (3.0 to 29.1)	0.9	7	0.5	2,453	15	0.036	3	0.083
15 - 19	32	75.0 (50.3 to 111.9)	7.5	97	6.1	4,021	5	0.599	0.1	0.706
20 - 24	68	212.5 (167.5 to 269.5)	21.3	247	15.7	3,637	8	0.333	0.0	0.848
25 - 29	102	318.8 (262.5 to 387.0)	31.9	532	33.8	5,213	9	0.227	0.0	0.853
30 - 34	67	209.4 (164.8 to 266.0)	20.9	398	25.3	5,940	7	0.414	0.2	0.655
35 - 39	35	96.9 (68.1 to 137.8)	9.7	217	13.8	7,001	6	0.497	0.1	0.739
40 - 44	18	31.3 (16.8 to 58.1)	3.1	53	3.4	5,311	6	0.540	0	1.0
45 - 49	6	18.8 (8.4 to 41.7)	1.9	10	0.6	1,617	18	0.012	3	0.083
50 - 54	9	28.1 (14.6 to 54.1)	2.8	11	0.7	1,269	15	0.036	3	0.083
55 - 59	0	0.0 -	0.0	-	0.0	-	-		-	
60 - 64	0	0.0 -	0.0	-	0.0	-	-		-	
65 - 69	0	0.0 -	0.0	-	0.0	-	-		-	
70 - 79	0	0.0 -	0.0	-	0.0	-	-		-	
80 +	0	0.0 -	0.0	-	0.0	-	-		-	

Rates are per 1000 injury claims. CI: Confidence Interval. Percentage totals do not equal 100% due to data rounding. The denominator used in the injury rate was the total of all claims. Thus, these rates are numerically identical to the percentages in this table and should not be interpreted as a measure of injury incidence.

Discussion

The ACC earnings-related compensations claims files that are lodged when an injury is seen by a health care provider is the only recording mechanism for rugby league injuries in New Zealand, although the data gathered through this system should not be seen as reflective of the total injury incidence of female rugby league participants.[169] The results could be biased as they exclude female rugby league participants that do not make injury claims for more minor injuries.[169] However these results highlight the number of injuries over an eight year recording period that were severe enough to require medical reporting. As there was no participation, training or match-related data, comparisons between costs of injury claims and training and match exposure time could not be undertaken. There was no indication whether the injury claims recorded were for new or recurrent injuries or an exacerbation of a previous injury. The mean cost per claim ($4,913 [£1,872]) was greater than the mean (£467 [$1,257]), median direct (£28 [$76]) or median indirect (£77 [$207]) costs per playing injury previously reported[72] but similar to the mean costs reported by King et al.[158] This difference may be reflective of the limitations of previous studies identified by Gabbett.[72]

The actual number of participants in rugby league activities is unknown as there is currently no recording system in New Zealand for this information. One study[111] reported that the total number of rugby league participants in New Zealand in 2005 was 21000 and that this has decreased to 16728 in 2009[9] This included junior, amateur male, female and masters participants. Unfortunately there is no breakdown on the playing numbers at the different participation levels and the number of females participating in rugby league in New Zealand remains unknown. Despite this, the aim of this study was to identify the number and circumstance of women's injury claims and associated costs that occurred from participating in rugby league activities in New Zealand over an eight year period. Unfortunately there is a paucity of studies looking at injuries from participation in women's rugby league with which to compare these results.

Apart from the likelihood of their being fewer women rugby league players, when compared with other studies in rugby league injuries, it appears that females (6%) incur fewer injuries in rugby league than males (94%).[158] A possible hypothesis for this low number of injury claims is that females participate in contact sport with less aggressiveness than males. This has been previously suggested and investigated for all women's sport and the results identified that there are gender similarities in the attitudes of athletes in areas such as aggression, physical danger and injury.[252] Women athletes have demonstrated that they are as willing as males to expose themselves to physical risk, injury and aggression.[252] Another suggestion for the difference in the injury incidence is the differences in the physicality and speed of female players when compared with male players. Gabbett's[91] study on elite female rugby league players reported that they had a slower speed and agility, lower muscular power, lower estimated maximal aerobic power and a greater body mass and skinfold thickness than male participants. A third possible difference may be there are less women playing rugby league in New Zealand when compared with male rugby league participation. However there are no available participation data to enable a comparison to be undertaken.

Not every district in New Zealand has women participating in rugby league activities. Some districts have only recently begun women's rugby league competitions while some districts only participate in national tournaments. It appears that the history of the establishment of women's rugby league in New Zealand is similar to other countries[167] and has been left to a few people motivated to support and administer the game in the different districts. Matches are typically held on a Sunday and some participants reportedly participate in other sporting activities prior to the matches on Sundays. This may result in players carrying unresolved injuries into the match resulting in a higher injury entitlement claim incidence.

National tournaments for women's rugby league are typically held annually for the selection of the New Zealand representative team, the 'Kiwi Ferns'. These tournament formats can vary from a weekly home-and-away competition to teams from several districts gathering in one location and participating in several matches held over a short period of time.[150] The recognition of the importance for selection in the national team to participate in international competitions may be reflected in the incidence over the years as shown in Table 38. The Women's Rugby League World Cup was held in 2000, 2005 and then again in 2008. The incidence of injury claims was higher in the 1999-2000 reporting period than in the following four years before it again rose in the later part of the study period reflecting the periods surrounding the World Cup competitions. More detailed epidemiological studies need to be undertaken to identify if there is any correlation between the number of female participants and the international women competitions that occur.

Although the incidence of injury claims for concussions (37 per 1000 injury claims) was higher than the injury rate reported for total injury claims (18 per 1000 injury claims)[157] the percentage of costs for these claims were similar (5% vs. 6%[157]). As a result, the mean cost per injury claim for concussions were the highest of all the injury type mean costs. This difference may be reflective of other studies reporting that females were more likely to report concussions than males.[26] Suggested factors for this may be biological differences, gender bias, socialization and social roles that females undertake.[23] Other research has suggested female athletes may be at an increased risk of incurring a concussion due to smaller size and weaker neck muscles when compared with male athletes,[21] and this is an area that warrants further research in all female sporting activities.

The percentage of lower limb injuries (65%) recorded in this study was similar to that recorded for women's rugby union (44%;[221] 46%;[33] 52%;[41] and 66%[52]) and rugby league[150] (55%) but higher than the total MSC injury site claims (42%).[157] The percentage of costs (59%) recorded in this study for lower limb injury claims was proportionally higher than that reported for all MSC injury costs (32%).[157] Lower limb injuries are common in many sporting activities[241] and females are reported to be almost twice as likely to sustain an injury to this area when compared with males.[36] The high frequency (65%) and cost proportion (59%) for lower limb injuries was higher in our study for females than in male rugby league players (previously reported as 42% of the injury claims and 32% of the total injury claim costs for the lower limb). Studies[157] have also reported that while gender discrepancies for lower limb injuries are not fully understood, lower limb kinematics during running may be a contributing factor.[36] Gender–specific morphology of the pelvis and thigh may also contribute to the differences identified when running.[36] With the differences in lower limb kinematics, there is the possibility that female lower limbs attain maximum muscular limits faster when running than males, and are possibly more susceptible to the onset of fatigue effects.[36] Studies involving fatigue have identified that kinematic adjustments do occur when the muscle is exhausted[48] and that there is an increased risk of a running related injury occurring as a result of these changes.[80] Further research is warranted to see whether injury reduction programs such as weight and strength training of the lower limbs and lower back and pre-season fitness development can assist in the reduction of injuries to the lower limb in women's rugby league participants.

Conclusions

This study has reported the lacuna of information in regards to the costs and incidence of injury claims for women rugby league participants. While it is important in understanding the costs incurred and how injuries were sustained across injury sites, injury types, age categories, and regions in the country, the data do not provide information on: (1) How the injuries occurred; (2) Whether they occurred as a result of match or training activities; nor (3) At what stage of the match the injuries occurred. The need for further studies into women's rugby league injuries are therefore warranted to enable identification of the incidence, site and type of injuries that occur from participation in rugby league activities and to assist in understanding the types of injuries that can occur for women. The results of these studies can assist in tailoring injury prevention programs towards women participants and will assist in covering the lacuna of data on women's rugby league injuries. Initial injury prevention programmes should focus on the 25-29 age group and address ways to prevent concussion and lower limb injuries.

What is already known on this topic?

There is scarce information on rugby league injuries in female players despite domestic, national and international competitions being played.

What this study adds

There were 320 moderate to serious injuries for female rugby league players over the eight years giving a mean ±SD of 38 ±10 injury claims per year and $196,514, ±$99,133 [£76,066, ±£38,374] cost per year. The lower limb accounted for 65% of the total female injury claims and 59% of total injury costs ($922,296 [£356,968]). The 25-29 age group recorded 32% of injury claims and 34% of injury costs. Concussion / brain injuries had the highest mean cost per claim ($7,033 [£2,724]). Injury prevention programmes for women's rugby league should focus on the 25-29 age group and address ways to prevent concussion and lower limb injuries.

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CHAPTER 7: A RETROSPECTIVE REVIEW OVER 1999 TO 2007 OF HEAD, SHOULDER AND KNEE SOFT TISSUE AND FRACTURE-DISLOCATION INJURIES IN RUGBY LEAGUE IN NEW ZEALAND

This chapter comprises the following paper submitted to the *International Journal of Sports Medicine.*

Reference

King, DA., Hume, P., Milburn, P. & Gianotti, S. A retrospective review over 1999 to 2007 of head, shoulder and knee soft tissue and fracture-dislocation injuries in rugby league in New Zealand. Submitted to *International Journal of Sports Medicine*.

Author contributions

King, D.A. 80%; Hume, P. 10%; Gianotti, S. 5%; Clark, T. 5%

Overview

King et al. [157] reported that of 5,941 moderate to serious claims resulting in medical treatment for rugby league injuries, the knee, shoulder, and head and neck body sites and soft tissue and fracture-dislocation injuries were most frequent and costly in the New Zealand national no-fault injury compensation corporation database during 1999 to 2007. However, additional analyses of knee, shoulder and head and neck body sites by soft tissue and fracture-dislocation injury types was required to enable a greater understanding of the nature of injuries most likely to be seen by sports medical personnel dealing with rugby league players. From 1999 to 2007 head and neck soft tissue injury claims (χ^2=26) and costs (χ^2=263), fracture-dislocation injury claims (χ^2=30) and costs (χ^2=279), shoulder soft tissue injury claims (χ^2=108) and costs (χ^2=783) and fracture-dislocation injury claims (χ^2=97) and costs (χ^2=1252) significantly increased. Knee soft tissue injury claims (χ^2=259) and costs (χ^2=1359) significantly decreased from 1999 to 2007. There was no significant difference in knee fracture-dislocation injury claims (χ^2=13, df=7, p=0.838) but there was a significant increase in knee fracture-dislocation injury costs (χ^2=160) from 1999 to 2007. Changes in the nature of injuries may be related to changes in defensive techniques employed in rugby league during this time. Sports medical personnel dealing with rugby league players should focus their injury prevention strategies on reducing musculoskeletal injuries to the head and shoulder. There should be a focus on increasing awareness of correct tackling technique, head injury awareness and management of suspected cervical spine injuries.

Introduction

Rugby league is a contact sport that is played internationally at junior, amateur, semi-professional and professional levels of participation [78]. As rugby league is an intermittent collision sport, the game requires participants to compete with a combination of muscular strength, stamina, endurance, speed, acceleration, agility, flexibility and aerobic endurance [180]. There is a risk of musculoskeletal injury occurring from both match and training activities due to the number of physical collisions and tackles that occur [159]. The most common injury sites have varied by different participation levels (professional rugby league: head and neck, knee and lower limb; semi-professional: shoulder, thigh and calf; amateur: head and neck, thigh and lower leg; junior: knee, shoulder) [159]. Injury type frequency has also varied by participation level with haematomas and sprains (professional, semi-professional and amateur) and fractures (junior) most frequent [159]. King et al. [157] reported that of the total 5,941 moderate to serious claims (MSC) resulting in medical treatment for rugby league injuries, the knee (n=1,338, 23% of total claims, 225 per 1,000 total rugby league injury claims, $8,750,147 total costs, 20% of total costs), shoulder (1,006, 17%, 169/1,000, $6,856,788, 17 %) and head and neck (565, 10%, 95/1,000, $9,314,686, 22%) body sites were most frequent and costly in the New Zealand ACC national no-fault injury compensation corporation database during the period 1999 to 2007. King et al. [157] also reported that the most frequent and costly injury types were soft tissue injuries (n=2817, 47%, 474 /1,000, $17,324,214, 41% of total costs) and fracture-dislocation injuries (2618, 44.1%, 440/1,000, $16,935,094, 40%).

Previous studies reporting injuries in rugby league have not provided data on the injury types by the injury sites. Knowledge of the types of injuries that occur to a specific body region such as the knee, shoulder and head and neck may assist in increasing sideline management preparation for the team medical personnel. Musculoskeletal injuries can result in socioeconomic impacts such as career limitations, increased medical costs and loss of income to the injured player [159]. Former sports participants are more likely to be hospitalized for musculoskeletal disorders. Sports injuries have significant negative side-effects for the sports participant, the sports team and society at large in both the short and long term [229].

Therefore, the aim of this study was to provide analyses of knee, shoulder and head and neck body sites by soft tissue and fracture-dislocation injury types to enable a greater understanding of the nature of injuries most likely to be seen by sports medical personnel dealing with rugby league players.

Methods

The study used a descriptive epidemiology approach. There is no reliable data capturing system for injuries in rugby league through the national sports organisation. New Zealand's national taxpayer funded no-fault injury compensation system, administered by the Accident Compensation Corporation (ACC), was utilised to provide detailed descriptive epidemiological data including costs associated with treatment for injuries that occur in rugby league activities. Details of this government taxpayer-funded monopoly that provides a 24 hr no-fault personal injury scheme are detailed elsewhere [111]. The ACC database records the number of injury claims but is unable to report missed match and training time, hospitalization duration and level of participation.

ACC categorises the rugby league claims made as minor or moderate to serious claims (MSC) [111]. We focused on MSC claims that occurred between 1st July 1999 and the 30th June 2007 as a result of participating in rugby league activities. Rugby league injuries to the knee, shoulder and head and neck body sites were extracted as they accounted for over half of the total ACC MSC costs and number of claims for rugby league over the study period as identified by King et al. [157]. Head and neck sites included the face, cervical spine, eye, ear, and nose. A subset dataset was created for soft tissue and fracture-dislocation injuries to these body sites given they were the most frequent (91% of knee injury claims, 44% of shoulder injury claims and 38% head and neck injury claims) and costly injury types identified by King et al. [157].

Ethical consent for the research was obtained from the Auckland University of Technology Ethics Committee (AUTEC 08/30) and the ACC ethics committee. The study meets the ethical standards of the *International Journal of Sports Medicine* [129].

All data were analyzed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of injuries per 1,000 MSC rugby league injury entitlement claims [135] and reported as means and standard deviations with 95% confidence intervals (CI). The injury rates and patterns were compared between reporting years (df=7) using a chi-squared (χ^2) test with significance set at $p<0.01$. Injury incidence was not calculated for the study as rugby league participation rates were not available as part of the data analysis. All costs are reported in New Zealand Dollars (NZD$000).

Results

Injury numbers, rates, percentages and associated costs for head and neck, shoulder and knee injuries by total injuries, soft tissue injuries and fracture-dislocation injuries for 1st July 1999 to 30th June 2007 varied by reporting year (see Table 45). Head and neck soft tissue injury claims (χ^2=26) and costs (χ^2=263) and fracture-dislocation injury claims (χ^2=30) and costs (χ^2=279) significantly increased from 1999 to 2007. Shoulder soft tissue injury claims (χ^2=108) and costs (χ^2=783) and fracture-dislocation injury claims (χ^2=97) and costs (χ^2=1252) significantly increased from 1999 to 2007. Knee soft tissue injury claims (χ^2=259) and costs (χ^2=1359), significantly decreased from 1999 to 2007. There was no significant difference in knee fracture-dislocation injury claims (χ^2=13, df=7, p=0.838) but there was a significant increase for knee fracture-dislocation injury costs (χ^2=160) from 1999 to 2007.

Table 45: Number, rate, 95% confidence interval and total and mean costs (NZD$000) and percentages of head and neck, shoulder and knee injuries by total, soft tissue and fracture-dislocation injuries for 1st July 1999 to 30th June 2007.

	Total injury				Soft tissue injury				Fracture-dislocations			
Yr	No	Rate *(95% CI)* %[a]	$000 *(%)*[b]	Mean $	No	Rate *(95% CI)* %[c]	$000 *(%)*[d]	Mean $	No	Rate *(95% CI)* %[e]	$000 *(%)*[f]	Mean $
Head/Neck												
99-00	51	81.3 *(61.8 to 107.0)* 1.8	889 *(2.1)*	17,431	18	28.7 *(18.1 to 45.6)* 0.6	107 *(0.6)*	5,944	19	30.3 *(19.3 to 47.5)* 0.7	92 *(0.5)*	4,842
00-01	44	81.6 *(60.7 to 109.7)* 1.5	873 *(2.0)*	19,841	20	37.1 *(23.9 to 57.5)* 0.7	110 *(0.6)*	5,500	17	31.5 *(19.6 to 50.7)* 0.6	97 *(0.6)*	5,706
01-02	52	103.4 *(78.8 to 135.7)* 1.8	1053 *(2.5)*	20,250	15	29.8 *(18.0 to 49.5)* 0.5	91 *(0.5)*	6,067	16	31.8 *(19.5 to 51.9)* 0.6	107 *(0.6)*	6,688
02-03	45	92.8 *(69.3 to 124.3)* 1.5	935 *(2.2)*	20,778	19	39.2 *(25.0 to 61.4)* 0.7	113 *(0.7)*	5,947	22	45.4 *(29.9 to 68.9)* 0.8	148 *(0.9)*	6,727
03-04	70	113.3 *(89.6 to 143.2)* 2.4	990 *(2.3)*	14,143	29	46.9 *(32.6 to 67.5)* 1.0	174 *(1.0)*	6,000	33	53.4 *(38.0 to 75.1)* 1.3	190 *(1.1)*	5,758
04-05	93	98.5 *(80.4 to 120.7)* 3.2	1,119 *(2.6)*	12,032	34	36.0 *(25.7 to 50.4)* 1.2	180 *(1.0)*	5,294	45	47.7 *(35.6 to 63.8)* 1.7	242 *(1.4)*	5,378
05-06	92	86.5 *(70.6 to 106.2)* 3.2	1,503 *(3.5)*	16,337	34	32.0 *(22.9 to 44.8)* 1.2	209 *(1.2)*	8,708	37	34.8 *(25.2 to 48.0)* 1.4	242 *(1.4)*	6,541
06-07	118	101.5 *(84.8 to 121.6)* 4.1	1,952 *(4.6)*	16,542	44	37.9 *(28.2 to 50.9)* 1.6	327 *(1.9)*	7,432	37	31.8 *(23.1 to 43.9)* 1.4	327 *(1.9)*	8,838
All years	565	95.1 *(87.6 to 103.3)* 19.4	9,314 *(21.8)*	16,485	213	35.9 *(31.3 to 41.0)* 7.6	1,311 *(7.6)*	6,150	226	38.0 *(33.4 to 43.3)* 8.6	1,445 *(8.6)*	6,469
Shoulder												
99-00	95	151.5 *(123.9 to 185.3)* 3.3	622 *(1.5)*	6,547	38	60.6 *(44.1 to 83.3)* 1.3	225 *(1.3)*	5,921	55	87.7 *(67.3 to 114.3)* 2.1	265 *(1.6)*	4,818
00-01	79	146.6 *(117.6 to 182.7)* 2.7	450 *(1.1)*	5,696	30	55.7 *(38.9 to 79.6)* 1.1	166 *(1.0)*	5,533	43	79.8 *(59.2 to 107.6)* 1.6	247 *(1.5)*	5,744
01-02	85	169.0 *(136.6 to 209.0)* 2.9	481 *(1.1)*	5,659	38	75.5 *(55.0 to 103.8)* 1.3	231 *(1.3)*	6,079	39	77.5 *(56.6 to 106.1)* 1.5	260 *(1.5)*	6,667
02-03	75	154.6 *(123.3 to 193.9)* 2.6	559 *(1.3)*	7,453	31	63.9 *(45.0 to 90.9)* 1.1	185 *(1.1)*	5,968	42	86.6 *(64.0 to 117.2)* 1.6	283 *(1.7)*	6,738
03-04	101	163.4 *(134.5 to 198.6)* 3.5	555 *(1.3)*	5,495	38	61.5 *(44.7 to 84.5)* 1.3	228 *(1.3)*	6,000	59	95.5 *(74.0 to 123.2)* 2.3	339 *(2.0)*	5,746
04-05	156	165.3 *(141.3 to 193.3)* 5.4	817 *(1.9)*	5,237	70	74.2 *(58.7 to 93.7)* 2.5	370 *(2.1)*	5,286	82	86.9 *(70.0 to 107.9)* 3.1	441 *(2.6)*	5,378
05-06	196	184.4 *(160.3 to 212.1)* 6.7	1228 *(2.9)*	6,265	81	76.2 *(61.3 to 94.7)* 2.9	497 *(2.9)*	6,136	109	102.5 *(85.0 to 123.7)* 4.2	712 *(4.2)*	6,532
06-07	219	188.5 *(165.1 to 215.2)* 7.5	2144 *(5.0)*	9,790	96	82.6 *(67.6 to 100.9)* 3.4	714 *(4.1)*	7,438	117	100.7 *(84.0 to 120.7)* 4.5	1,033 *(6.1)*	8,829
All years	1006	169.3 *(159.2 to 180.1)* 34.6	6,856 *(16.0)*	6,815	422	71.0 *(64.6 to 78.1)* 15.0	2,516 *(14.5)*	5,960	546	91.9 *(84.5 to 99.9)* 20.9	3,580 *(20.9)*	6,469
Knee												
99-00	161	256.8 *(220.0 to 299.7)* 5.5	868 *(2.0)*	5,391	142	226.5 *(192.1 to 267.0)* 5.0	842 *(4.9)*	5,930	17	27.1 *(16.9 to 43.6)* 0.6	82 *(0.5)*	4,824
00-01	146	270.9 *(230.3 to 318.6)* 5.0	740 *(1.7)*	5,068	132	244.9 *(206.5 to 290.5)* 4.7	729 *(4.2)*	5,523	14	26.0 *(15.4 to 43.9)* 0.5	80 *(0.5)*	5,714
01-02	122	242.5 *(203.1 to 289.6)* 4.2	654 *(1.5)*	5,361	117	232.6 *(194.1 to 278.8)* 4.2	607 *(3.5)*	5,188	7	13.9 *(6.6 to 29.2)* 0.3	47 *(0.3)*	6,714
02-03	100	206.2 *(169.5 to 250.8)* 3.4	563 *(1.3)*	5,630	93	191.8 *(156.5 to 235.0)* 3.3	555 *(3.2)*	5,968	8	16.5 *(8.2 to 33.0)* 0.3	54 *(0.3)*	6,750
03-04	114	184.5 *(153.5 to 221.6)* 3.9	692 *(1.6)*	6,070	100	161.8 *(133.0 to 196.8)* 3.5	600 *(3.5)*	6,000	13	21.0 *(12.2 to 36.2)* 0.5	75 *(0.4)*	5,769
04-05	193	204.4 *(177.5 to 235.4)* 6.6	1,260 *(2.9)*	6,528	174	184.3 *(158.9 to 213.8)* 6.2	919 *(5.3)*	5,282	18	19.1 *(12.0 to 30.3)* 0.7	97 *(0.6)*	5,389
05-06	240	225.8 *(198.9 to 256.2)* 8.3	1,555 *(3.6)*	6,479	218	205.1 *(179.6 to 234.2)* 7.7	1,338 *(7.7)*	6,138	17	16.0 *(9.9 to 25.7)* 0.6	111 *(0.7)*	6,529
06-07	262	225.5 *(199.8 to 254.5)* 9.0	2,418 *(5.6)*	9,229	236	203.1 *(178.8 to 230.7)* 8.4	1,755 *(10.1)*	7,436	22	18.9 *(12.5 to 28.8)* 0.8	194 *(1.1)*	8,818
All years	1338	225.2 *(213.5 to 237.6)* 46.0	8,750 *(20.4)*	6,540	1,212	204.0 *(192.8 to 215.8)* 43.0	7,345 *(42.4)*	6,058	116	19.5 *(16.3 to 23.4)* 4.4	740 *(4.4)*	6,466

Rates are per 1,000 MSC rugby league injury claims. CI: Confidence interval. Percentage of (a) = total number of injury entitlement claims; (b) = total injury entitlement costs; (c) total number of soft tissue injury entitlement claims; (d) = total amount of soft tissue injury entitlement costs; (e) total number of fracture-dislocation injury entitlement claims; (f) = total amount of fracture-dislocation injury entitlement costs.

Discussion

The significant increases in claims and costs from 1999 to 2007 for head fractures and soft tissue injuries, shoulder fracture-dislocations and soft tissue injuries need to be addressed. Previous studies reporting severe cervical spinal cord injuries[24] have shown an increase in the number of injuries to the cervical spine as a result of multiple tacklers involved in the tackle situation in rugby league with the ball carrier more commonly injured than the tackler.[24] The current data set did not include the environment that the injury occurred in nor the role in which the injured person was undertaking (tackler vs. ball carrier) when the injury occurred. This study was unable to determine whether any of the injuries to the head and neck resulted in catastrophic or life changing situations (e.g. post-concussion syndrome, tetraplegia) as a result of rugby league activities.

Although not the most common injury site in our study, the shoulder has been reported to be the most common injury site in some,[159] but not all,[69] studies in rugby league. In a recent position statement on prevention of acute sports injuries[229] acute shoulder injuries were common in sports involving body contact. No published studies to date have looked at the impact of the tackle on the shoulder through direct (fall or blow) or indirect (transmission) forces in any sporting code and therefore there is no evidence for the identification of risk factors associated with acute shoulder injuries.[229] The increase in the rate of shoulder injuries reported in our study may be related to a change in tackling styles employed. Unfortunately there was no distinction reported between training and match activities in the ACC database so no comparison could be undertaken to identify if the increase was match or training related. The concern is that although the yearly number of injury claims for the shoulder tripled over the study period, the associated costs for shoulder injuries in rugby league was nearly quadruple for the same reporting period. This increase in costs may be reflective of the changes in severity of the injuries to the shoulder and the tackling styles employed.
The most common injuries to the shoulder in matches are acromioclavicular joint injuries (32%) and rotator cuff/shoulder impingement injuries (23%), but injuries resulting in dislocation or instability to the shoulder (14%) resulted in the greatest portion of missed matches.[131] Training injuries to the shoulder were similar with acromioclavicular joint injuries (60%) being the most common injuries reported.

The decrease in the rate of knee injuries may be related to tackling styles but there are no published studies reporting changes in tackling styles to enable further analysis to be completed. Female athletes have a three- to six-fold higher incidence of non-contact ACL injuries than male athletes but the reason for this is not clear.[229] Other considerations in determining the cause of knee injuries are shoe-surface friction with different forces produced by different shoe type's worn, [229] different playing surface grass types and environmental conditions with more knee injuries being reported to occur with a high water evaporation and low rainfall.[192]

The cost of knee soft tissue injury claims reflects the complexity of the knee as a joint. For example, costs associated with treatment for anterior cruciate ligament injuries over a five year period have been reported to average $10,940 ±8,914 per MSC.[112] Other knee ligament costs were less, averaging $9,346 ±6,214 per injury claim. The mean cost per injury claim for knee soft tissue injury claims ($6,058) and knee fracture-dislocations ($6,466) were lower in our study. Not reported were the types of injuries (ligament strains, cruciate ligament ruptures, dislocations etc.) that occurred which may vary depending upon the number and associated costs per injury entitlement claim.
Although the mean and total costs of rugby league injuries have been previously reported,[157] the exploration of injuries by injury sites is useful for medical personnel. Knowledge of the most costly or frequently injured body sites as a result of rugby league activities enables forward planning in terms of injury prevention or injury management. Medical services such as hospitals, physiotherapists etc. can prepare to plan for the required medical equipment and personnel to assist in the management of these injuries. Despite a growing knowledge base of injuries that occur from rugby league activities, there is a paucity of research specifically reporting the costs associated with rugby league participation which would further support injury prevention program implementation and possible rule modification for a reduction of injuries in rugby league.

The changes in the costs and number of injury claims may be reflective of the changing style of match play seen in rugby league. Dominance of the tackle contest, the ability to tolerate physical collisions that occur in the tackle and tackling ability is important for success in rugby league.[100] Changes in defensive strategies at the professional level of participation showed that by increasing the number of defenders in the tackle the play-the-ball was slowed down.[100] This change in defence saw more players involved in tackling the opposition players, tackling around the shoulder area to stop the offloading of the ball and more effort in stopping the forward motion of the ball carrier with the aim to dominant the tackle and slow down the play-the-ball. As a result of the success of this style of defensive strategy other teams in the competition, and in other competitions, endeavoured to emulate the defensive strategies employed.[100] This may be reflective in the amateur rugby league injuries reported in this, and a previous study,[157] by the increase in injuries to the head and neck. It is suggested that medical personnel should focus their injury prevention efforts on increasing awareness of correct tackling technique, head injury awareness and management of suspected cervical spine injuries. The findings of our study should not been seen as being reflective of the total injury incidence for head and neck, shoulder and knee body sites from rugby league participation in

New Zealand. As a result of the only recording mechanism for rugby league injuries in New Zealand being through the lodgement of injury claims through ACC,[157] bias in the results could not be excluded as the data excludes injuries of rugby league participants that do not make injury entitlement claims.[169] The findings do highlight the reported costs and number of injuries over the study period of those injuries severe enough to require medical assistance and further rehabilitation. As there was no match or training related data available, further analyses could not be undertaken to identify costs and number of injury entitlement claims with respect to match and training exposure time. There was also no way to identify if the reported injury claims were due to an exacerbation of a previous injury from rugby league participation that did not meet the MSC criteria.

Our data analysis has not provided information on how the injuries to the body sites occurred, what participation level the injuries occurred at, whether the injuries occurred as a result of match or training activities or at what stage of the match or training environment the injuries occurred. Another consideration is how anthropometric and physiological profiles may affect injury. There are currently no published studies on amateur rugby league anthropometric and physiological profiles in New Zealand. Further studies with specific details on injury mechanisms, physical characteristics of players and participation data are warranted to further explore the incidence of injury that occur from rugby league participation in New Zealand to enable injury prevention strategies to be developed in regards to injuries to the head and neck, shoulder and knee. Longitudinal studies are also warranted to further establish the incidence of rugby league injury sites by injury types to enable a broader understanding of the injuries that occur from rugby league participation.

Conclusions

From 1999 to 2007 there were significant increases in claims and costs for head fractures and soft tissue injuries and shoulder fracture-dislocations and soft tissue injuries, but significant decreases in knee soft tissue injury claims. Sports medical personnel dealing with rugby league players should focus their injury prevention strategies on reducing musculoskeletal injuries to the head and shoulder. It is suggested that there should be a focus on increasing awareness of correct tackling technique, head injury awareness and management of suspected cervical spine injuries.

CHAPTER 8: BACK AND SPINE INJURIES IN AMATEUR RUGBY LEAGUE: A REVIEW OF NINE YEARS OF ACCIDENT COMPENSATION CORPORATION INJURY ENTITLEMENT CLAIMS AND COSTS

This chapter comprises the following paper submitted to *Journal of Science and Medicine in Sport.*

Reference

King, DA., Hume, Gianotti, S., & Clark, T. Back and spine injuries in amateur rugby league: A review of nine years of Accident Compensation Corporation injury entitlement claims and costs. *Submitted to Journal of Science and Medicine in Sport.*

Author contribution:

King, D. 85%; Hume, P. 10%; Gianotti, S. 3%; Clark, T. 2%

Overview

Rugby league is a popular participation sport, but there have been concerns raised regarding the possible high number of severe neck, back and spine injuries. Therefore an epidemiological overview of rugby league neck, back and spine injuries and associated costs of these injuries was undertaken in one country over nine years. The New Zealand national Accident Compensation Corporation data for moderate to serious injury entitlement claims (MSC) over nine years were analysed for the number, type and cost of neck, back and spine rugby league injuries resulting in medical treatment. There were 206 (3%) neck, back and spine MSC claims totalling NZD$1,585,927 (4%) of the total injury entitlement costs for rugby league over the nine-year period. The rate of MSC neck, back and spine rugby league injuries was 26 per 1,000 total rugby league claims. Although the rate of neck, back and spine injuries varied over the nine years from 22 to 40 per 1,000 injury claims, there was a significant increase over the duration of the study in the number of neck, back and spine MSC claims (χ^2=849, df=8, p<0.001), and the cost per MSC injury claim (χ^2=19054, df=8, p<0.001). The frequency, severity and first 12 months cost of neck, back and spine injuries in rugby league is an issue that needs to be addressed. Unfortunately the ACC data base does not provide information on how or why the injuries occurred. A prospective injury epidemiology study needs to be conducted that will allow collection of information surrounding the mechanisms of injury and possible causative risk factors such as tackling technique. In the meantime it is suggested that coaches should ensure tackling technique is correctly taught to all rugby league players to reduce the risk of neck, back and spine injury. Team medical personnel should be trained in dealing with neck and spine injuries as well as head related injuries, and emergency procedures in dealing with players with a suspected neck or back injury should be practiced at clubs.

Introduction

Rugby league is a popular participation sport, but there have been concerns raised regarding the possible high number of severe neck, back and spine injuries.[157] Injuries occur in rugby league at various rates depending upon the participation level of competition.[87] Typically the rugby league injury rate increases as the participation level increases.[87] Most injury studies in rugby league have reported an overall summary of the injuries recorded by team, club or over a limited period of time.[155] Some authors have also undertaken to report player specific data using variations in the injury types and sites by player position or player groups.[87] King et al[157] recently reported a summary of the injury rate, site, types, cost and geographical location over an eight year period for rugby league injury for a country. Despite the increasing amount of published studies reporting injuries from rugby league, to date there is no published study looking at specific injury types such as neck, back and spine injuries that occur from participation in rugby league activities. Similar to rugby union, neck, back and spine injuries do occur in rugby league.[209] These injuries are of particular concern as, although they are rare on the basis of exposure per player,[209] they can have severe to devastating outcomes[227] as a result of an injury occurring to this body region. The incidence of neck, back and spine injuries has been reported to have increased for rugby league from 1.8 to 2.9 per 100,000 players despite player numbers declining over the reporting period and the tackle was the most common cause, especially where there were two or more tacklers involved.[227]

Measures have been undertaken in rugby union to prevent neck and back injuries and these have included changes to the laws relating to the scrum procedures, stricter application of the existing laws and educational initiatives for the prevention of neck and back injuries.[24, 130, 210, 249] Unlike rugby union, where the cause of spine injuries reportedly occurs in the scrum (13 to 40%), the tackle (36 to 51%), and or during rucks and mauls (18 to 23%),[177, 209] the most common causative mechanism for neck, back and spine related injuries in rugby league is the tackle (78%).[209] Relatively rare in regards to the exposure per sports participant, spinal cord injuries have the potential for catastrophic injuries to occur. These injuries can result in devastating, neurological consequences as well as psychological, financial and economical consequences to the player, their family and the wider community.[20]

With this in mind, the aim of this study was to provide an epidemiological overview of rugby league neck, back and spine injuries and the associated costs of these injuries in one country (New Zealand) over nine years. New Zealand's national taxpayer funded no-fault injury compensation system administered by the Accident Compensation Corporation (ACC) means that New Zealand is uniquely positioned to provide detailed descriptive epidemiological data including costs associated with treatment for these injuries. Using these data, comparisons of the rate, type and cost of back and spine rugby league injuries over nine years were conducted.

Methods

The details and limitations of how the ACC database source has been established have been previously reported.[157] The ACC data obtained for new and ongoing moderate to serious entitlement claims (MSC) for rugby league injuries covered the period 1st July 1999 to 30th June 2008. For the purpose of consistency and comparison, MSC were limited to a 12 month period from when they were lodged for the costs per claim. There were no reliable rugby league participation data collected by New Zealand Rugby League (NZRL) over the same period so match injury rates and details on possible risk factors such as phase of play were unable to be calculated. The areas recorded on the ACC database used in this study were the back, spine, neck and back of head.

All the data collected were entered into a Microsoft Excel spreadsheet and analyzed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of neck, back and spine rugby league MSC injuries per 1,000 MSC rugby league injury claims and reported as means with 95% confidence intervals (CI) where appropriate. Injury rates and patterns were compared between reporting years using a one sample chi-squared (χ^2) test. Significant p values reported in the text are less than 0.001 if they are not specifically stated. Match injury rates were not calculated for the study as rugby league participation numbers were not available as part of the data analyses. Median and inter-quartile costs were calculated and are reported in New Zealand Dollars (NZD$).

Ethical consent for the research was obtained from the Auckland University of Technology Ethics Committee. Informed consent from the injured players was not obtained as data were collected from the ACC database without individual player follow-up.

Results

Over the nine years there were a total of 7,239 MSC injury entitlement claims for rugby league. Of these claims 3% were neck, back and spine MSC claims resulting in 4% of the total MSC injury entitlement costs for rugby league. There were 206 (26, 95% CI: 22 to 29 per 1000 injury entitlement claims) MSC injury entitlement claims lodged over the study period (see Table 1). The total cost for head, neck and spine MSC's was NZD$1,585,927. This equated to an average cost of NZD$7,699 ±2,025 per neck, back and spine MSC injury entitlement claim. Although the rate of neck, back and spine injuries varied over the study period there was a significant increase in the number of neck, back and spine MSC claims (χ^2=849, df=8), and the mean cost per MSC injury (χ^2=19054, df=8) over the duration of the study.

Table 46: Number, rate and 95% confidence interval, and total, average ±SD, median and inter-quartile costs NZD$ of neck, back and spine rugby league injuries of moderate to serious injury entitlement claims for 1999 to 2008.

Year	No	Rate (95% CI)	%	Total $	Average $ Yr ±SD	Median $	Inter-quartile $ First $	Third $	Range $
99-00	18	28.7 (18.1 to 45.6)	8.7	145,555	8,086 ±17,365	1,616	816	8,802	7,985
00-01	12	22.3 (12.6 to 39.2)	5.8	61,124	5,094 ±4,986	2,794	971	9,389	8,418
01-02	13	25.8 (15.0 to 44.5)	6.3	71,487	5,499 ±9,890	1,757	739	3,631	2,892
02-03	12	24.7 (14.1 to 43.6)	5.8	31,399	2,617 ±2,118	1,748	1,193	3,919	2,725
03-04	14	22.6 (13.4 to 38.2)	6.8	81,391	5,814 ±11,550	1,614	960	3,847	2,888
04-05	38	40.2 (29.3 to 55.3)	18.4	343,914	9,050 ±12,817	2,773	1,102	10,081	8,979
05-06	24	22.6 (15.1 to 33.7)	11.7	408,123	17,005 ±53,222	1,561	681	11,230	10,549
06-07	41	35.3 (26.0 to 47.9)	19.9	284,414	6,937 ±10,005	2,367	1,002	7,784	6,782
07-08	34	26.2 (18.7 to 36.7)	16.5	158,521	4,662 ±5,656	2,000	1,159	5,789	4,629

Rates are per 1,000 MSC rugby league injury claims. CI: Confidence interval.

Discussion

The study was designed to investigate the number and cost of neck, back and spine new and ongoing MSC injury entitlement claims as a result of participation in rugby league activities in New Zealand over a nine-year period. The only recording mechanism available to enable capture of rugby league injuries in New Zealand is the ACC database. This is undertaken through the compensations claims (e.g., earnings-related) files that are lodged with ACC when a health care provider in New Zealand sees an injury. The statistics gathered through the use of this system should not be seen as being reflective of the total neck, back and spine injury incidence from rugby league participation in New Zealand.[169] Additionally, we did not analyse whether the MSC injury entitlement claims reported were new, recurrent or an exacerbation of previous neck and spine injuries. The large range recorded in the mean, standard deviation and median costs for neck, spine and back injuries may be a result of a cluster of very expensive claims and a cluster of very small claims.

The data provided from the ACC database was limited to a 12 month period as it was expected that the majority of the treatment related costs would occur in this time period. Only those claims made in the 12 month period were recorded and are reflective of the number of new injuries that have occurred during that period from rugby league participation. As a result, some injury related costs may not be included in the data as they may have: (1) Occurred outside of the 12 month data capture period; or (2) Only been partially captured in the injury entitlement costs reported.

There were few studies published on rugby league neck, back and spine injuries making statements on the extent of the problem in rugby league difficult. Neck and spine injuries have been reported to be more common in players in their early 20's, in competitive matches and to players undertaking roles in the forward positions.[24, 227] Unfortunately the current study could not present the injured player's role on the field, phase of play, or the type of activity undertaken (i.e., tackle, scrum, collision, running, etc.). Subsequent studies reporting neck and spine injuries should include these data to help identify injury causation. One way to capture these data is for a neck, back and spine register to be available. The NZRL, in conjunction with ACC, implemented the *Concussion Serious Injury* (CSI) reporting system in 2004. However, unless all people involved with teams are aware of the CSI, and understand why these injuries should be reported, the data captured are limited in use.

The increase in the number of neck, back and spine injuries from the 03-04 reporting period is a concern. There were no changes in the rules and regulation in rugby league in that reporting period that could be considered as attributing to this change in injury entitlement rate. This increase could be reflective of the increased focus on dominance in the tackle and change in tackling style observed in the National Rugby League in that period.[100] These changes saw faster line-speed defensive strategy with more players' involved in the tackle focussed on stopping the "offload" of the ball by wrapping the ball up in the tackle and thus slowing of the "play-the-ball".[100] More people involved in the tackle focusing on the upper body region may have resulted in more contact to the head and neck region. Further research is warranted to explore this supposition.

The cost of neck and spine related injuries have highlighted the need for more awareness of the potential for neck and spine injuries in rugby league activities through the use of injury prevention programs. Ideally there should be a qualified medic available for each team participating in rugby league activities that is appropriately trained to deal with this type of injury. Recent efforts by the NZRL have seen the implementation of the First Aid Officer course being available for all districts participating in rugby league activities as the first step in a pathway towards higher-level accreditation. Unfortunately, at the amateur level of participation, the recruitment of volunteers to complete these courses is difficult.[51] Similar problems exist in the funding and supply to recreational rugby clubs of appropriate medical and safety equipment designed to deal with neck and spine injuries. Even without the appropriate medical and safety equipment, personnel should be appropriately trained, and certified, to manage these injuries without causing any further detriment to any injury that may have occurred.

This study provides information that can be used to encourage and develop further long-term international studies on the incidence of neck, back and spine injuries in rugby league. An understanding of the magnitude and cost of neck and spine injuries is essential in promoting the need for injury prevention strategies. As amateur players are the largest group of players involved in rugby league in New Zealand, awareness of the nature of neck, back and spine injuries, and the reporting process available, will enable a broader database to be established. Further studies are warranted to explore the incidence of head, neck and spine injuries.

Conclusion

The frequency, severity and cost of neck, back and spine injuries in rugby league is an issue that needs to be addressed in order to reduce the ongoing cost to New Zealand in terms of ACC levies for treatment and compensation. Unfortunately the ACC data base does not provide information on how or why the injuries occurred. A prospective injury epidemiology study needs to be conducted that will allow collection of information surrounding the mechanisms of injury and possible causative risk factors such as tackling technique. In the meantime it is suggested that coaches should ensure tackling technique is correctly taught to all rugby league players to reduce the risk of neck, back and spine injury. Team medical personnel should be trained in dealing with neck and spine injuries as well as head related injuries, and emergency procedures in dealing with players with a suspected neck or back injury should be practiced at clubs.

Practical implications

- A prospective injury epidemiology study needs to be conducted that will allow collection of information surrounding the mechanisms of injury and possible causative risk factors such as tackling technique.

Acknowledgement

Thanks to Lorna Bunt for providing access to the ACC data enabling this study to be conducted

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CHAPTER 9: VIDEO ANALYSIS OF TACKLES IN PROFESSIONAL RUGBY LEAGUE MATCHES BY PLAYER POSITION, TACKLE HEIGHT AND TACKLE LOCATION

This chapter comprises the following paper submitted to: *International Journal of Performance Analysis in Sport.*

Reference

King, D., Hume, P., Clark, T. Video analysis of tackles in professional rugby league matches by player position, tackle height and tackle location. Submitted to *International Journal of Performance Analysis in Sport.*

Author contributions

King, D. 82%; Hume, P. 15%; Clark, T. 3%

Overview

This paper describes the nature, height, site and direction of tackles seen in professional rugby league. Retrospective observational analysis was conducted using videos of 80 rugby league matches from 2008. There were 50,019 tackles recorded representing 701 ±64 tackles per match. Nearly 50% of tackles involved tacklers from behind the visual fields of the ball carrier, most tackles involved either two or three tacklers and most tackles involved contact with the mid-torso and hip-thigh region of the ball carrier. Significantly more players were involved in the tackle in the first, than the second half of matches (χ^2=4.3, df=1, p=0.038). Significantly more tackles were recorded in the defence than the attack side of the field (χ^2=183.1, df=1). Forwards were more commonly involved in the tackle than backs (χ^2=4050, df=1). Forwards were significantly more involved in tackle events than backs but when viewed in player groups, adjustables were involved in significantly more tackle events than outside backs (χ^2=5630, df=1) and hit-up forwards (χ^2=3280, df=1). Coaches should focus on getting players to practice correct tackle technique during tackling with two or more players involved in the tackle and especially, when making a tackle in the ball carriers blind vision area.

Introduction

Originating in the north of England in the 1890's, rugby league is a full contact sport participated worldwide.[27, 87, 183] The game is played over two halves of 30 to 40 minutes duration depending on whether the level is junior,[92] amateur, [69, 151] sub-elite,[58] or elite.[116] Players compete in a challenging contest that typically involves bouts of high-intensity activities (e.g. sprinting, running, passing, and tackling) separated by short bouts of low-intensity activities (standing, walking, jogging).[78] The physiological demands of the game are complex and require players to have highly developed speed, agility, muscular strength and power, and maximal aerobic capacity.[87, 104].

Success in rugby league is dependent on the capacity of participants to tolerate physical collisions, and the ability to dominate in the tackle contest.[93] This is important for both attack and defence. The tackler must ensure that the ball carrier is slowed down in the 'play-the-ball', and conversely the ball-carrier tries to speed up the attacking phase to keep the defensive line moving backwards advancing the ball down the field towards the try line.[100] Research on tackles in rugby league have shown there is an association between several factors: (1) Anthropometric (stature, body mass, skinfold thickness, somatotype) and physiological (fast acceleration and change of speed) factors are associated with tackling ability with higher attributes associated with better tackling efficiency;[94] (2) Fast defensive line speed reduces tackling proficiency;[100] and (3) There is a direct relationship between the physiological capacities of players and fatigue-induced decrements in tackling technique.[93] The tackle is the most common cause of injury in rugby league at all levels of participation.[78]

Although there is an increasing body of information reporting these aspects of the tackle, no study has reviewed the characteristics of the tackle in rugby league in the match situation. In addition no studies have reported where the tackles most commonly occur, what side of the body and at what body height these occur. Basic tackle related information is available from various rugby league websites (e.g. www.nrlstats.com) for the number of tackles (including missed tackles) per half, per match and per player but this information does not give specifics such as tackle height, direction, field location and number of tacklers involved in the tackle. This information would be beneficial to assist in development of tackle technique training programs and assist in future injury prevention programs.

Game sports analysis is an approach that has been used in rugby union to measure changes in matches over a 32 year period[211] and to report on tackle characteristics and inciting events associated with an injury in rugby union.[212] More recently microtechnology (e.g. accelerometers, gyroscopes) analysis has been used to document the large number and intensity of physical collisions during the course of professional rugby league training sessions.[99] No study has reported the characteristics of tackles in match situations and in particular what occurs during tackles that result in injury.

Aim

The aim of this study was to identify and describe the nature, height, site, field location and direction of tackles seen in professional rugby league matches via video analysis.

Methods

Ethical consent

Ethical consent for the research was obtained from the AUT University Human Ethics Committee.

Procedure

Retrospective observational analysis was conducted using videos of televised rugby league matches. A total of 80 rugby league matches played throughout the 2008 year (20 international rugby league matches from the 2008 Rugby League World Cup, 30 randomly selected National Rugby League competition matches and 30 randomly selected National Youth Competition matches) were analysed by a single analyser with 10 years of rugby league coach and trainer experience.

Video data and definitions of tackles and related characteristics

Video analyses of televised coverage of matches allowed documentation of the nature of rugby league tackles. One analyst used *Sports Performer*© (Premier Concepts Pty Ltd, Sydney, Australia; http://www.sportsperformer.com.au) to code tackles noting the match date, venue, player number, number of tackle in the set, number of tacklers involved in the tackle, field location where the tackle occurred and whether the player was a ball carrier being tackled or was the tackler tackling a ball carrier. Slow time motion replay was used to further review the individual tackles and *ImageJ* (http://rsb.info.nih.gov/ij/) were used to measure the degree of approach from the face on direction (see Figure 1) of the tackler to the ball carrier. The use of one analyst ensured consistency in the application of the definitions for coding.

Definitions for tackles and related characteristics included:

a. *Tackle:* A successful tackle occurs when the ball carrier is held by one or more of the opposing players and either the ball or hand of the arm holding the ball makes contact with the ground or the ball carrier cannot make any further progress. Section 11 of the International Laws of Rugby League (http://admin.nrl.sportal.net.au/site/_content/document/00000682-source.pdf) was used to define a tackle in regards to how the ball carrier was held by the tackler(s) to complete the tackle.

b. *Missed tackle:* Any unsuccessful attempt to complete a tackle where the tackler/defender has made contact with the ball carrier and they have broken from the tackle before it is completed.

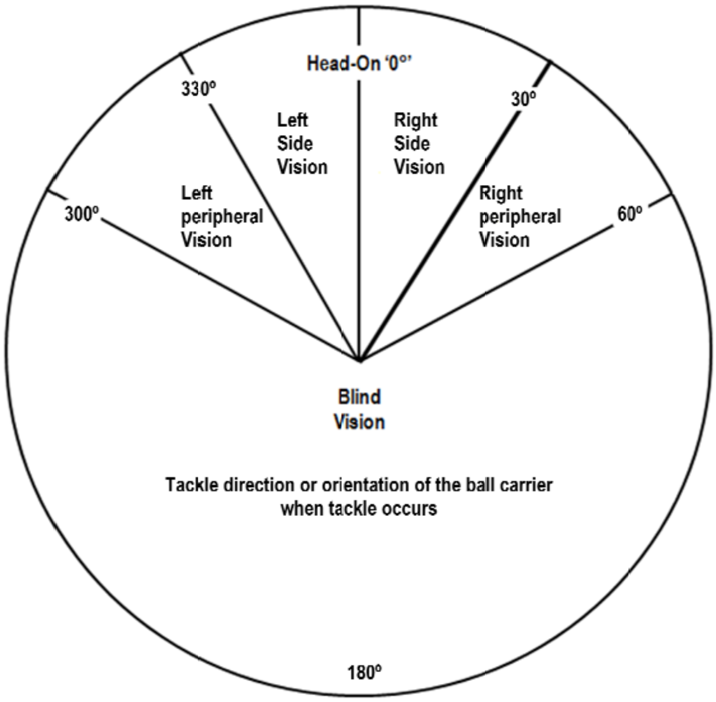

Figure 4: Tackle direction or orientation of tackler to ball carrier.

c. *Tackle number:* The team in possession of the ball is allowed five successive plays of the ball. The ball is handed over to the opposition after the fifth play of the ball or when the team in possession: (1) Is tackled a sixth time, commits an accidental breach (i.e. knock on, forward pass and possession changes team resulting in a 'zero tackle'); (2) Has a player held-up and unable to ground the ball in the opponents' in-goal; or (3) Kicks the ball directly into touch on the full.

d. *Tackle height:*[212] Classified according to five different regions of the body: (1) Lower legs – from the player's knees to their toes; (2) Hip and thigh – from above the player's knees to the player's hip level; (3) Mid-torso – from above the player's hip level to the level of the player's arm pit; (4) Shoulder – from the player's arm pit to the level of the shoulder including the arm; and (5) Head and neck – above the shoulder with any connection with the head and/or neck during the course of the tackle. When the injured player was the ball carrier, all tacklers involved in the tackle were recorded for tackle height. When the injured player was the tackler, only the injured player was recorded for tackle height.

e. *Tackle direction or orientation:*[106] Classified as: (1) Tackler being head-on to the ball carrier (0°); (2) Tackler being in the ball carrier's side vision (left side: 330° to 359°; right side 001° to 030°); (3) Tackler being in the ball carrier's peripheral vision (left side: 300° to 329°; right side: 031° to 060°) or in the ball carrier's blind vision (between 061° to 299°) when the tackle occurred. All tacklers involved in the tackle were recorded for tackle direction or orientation relative to the ball carrier's view.

f. *Field position:* Classified as either defence (the side in which the team must defend their own in-goal area in order to stop the opposition team scoring a try), or attack (the side in which the team must enter to score a try in the opposition in-goal area) halves of the field. A regulation field length is 100 metres with a maximum in-goal size of eight metres in depth. The field is divided into 10 metre sections marked from 0 (goal-line) to 50 (half-way) for both halves of the field.

Player position

Players were recorded by the position they were playing in when they were tackled. For further analysis player positional groups were also recorded:[91]

- *Adjustables:* Players in the hooker, halfback, five-eighth or stand-off and loose forward positions. The main role of players in the adjustables groups is to direct the ball in attack, co-ordinating the defensive effort in the forwards and be the team's main play-makers.
- *Hit-up forwards:* Players in the second row (n=2) and prop (n=2) positions. The main role of players in the hit-up forwards groups is to run directly into the opposition's territory to break the defensive line, tackle the opposition and offload the ball to a supporting player to switch the point of attack or create a gap to run through.
- *Outside backs:* Players in the fullback, centre (n=2) and wing (n=2) positions. The main role of players in the outside backs groups is to chase down and tackle any player who breaks the first line of defence, to breach the defensive line on their respective sides on attack and as a support player to take an offload and keep the ball alive, or to provide an overlap or a different angle of attack in the centre of the field.

Statistical analyses

Data were analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA) statistical software. Data were reported as means with 95% confidence intervals (CI) where appropriate.[139, 240] One-sample chi-squared ($\chi 2$) tests were used to determine whether the observed tackle frequency was significantly different from the expected tackle frequency. Significant p values reported in the text are less than 0.001 if they are not specifically stated.

Results

In the 80 matches analysed there were 50,019 tackles recorded representing 701 ±64 (mean ±SD) tackles (625 ±60 completed; 76 ±16 missed tackles) per match (see Table 47). Players recorded a mean of 32 ±15 tackles per match as the tackler and were tackled 21 ±4 times per match as the ball carrier.

Number of tacklers, tackle height, direction and degree of tackle position for tackles

For all levels of competition combined there were significantly more tackles involving two tacklers than one (χ^2=6177, df=1), three (χ^2=1080, df=1), or more than three (χ^2=17800, df=1) tacklers (see Table 2). This was similar for the International rugby league, National Rugby League and National Youth Competition levels.

More tackles involved contact with the hip and thigh region than the lower limb (χ^2=9573, df=1), mid-torso (χ^2=52, df=1), shoulder (χ^2=12578, df=1) and head and neck (χ^2=23225, df=1) regions and these were significant (see Table 48). This was similar for International rugby league and National Youth Competition levels of participation but not National Rugby League level of participation. There were more tackles involving the mid-torso region than the lower limb (χ^2=4157, df=1), shoulder (χ^2=4644, df=1) and head and neck (χ^2=10580, df=1) regions. Although only 5% of total tackles involved the head and neck region, the percentage of tackles involving the head and neck at the international rugby league level of competition (8%) was greater than National Rugby League (3%) and National Youth Competition (4%) levels of participation, but the differences were not significant.

Table 47: Observed and estimated tackles, exposure hours, completed missed tackles with 95% confidence intervals for level of competition (total, international rugby league, National Rugby League and National Youth Competition).

	Total	**International rugby league**	**National Rugby League**	**National Youth Competition**
Tackles observed	**50019**	12412	19523	18084
Tackles expected	**50019**	12504.8	18757.1	18757.1
Number of games played	**80**	20	30	30
Exposure hours	**2766.4**	691.6	1037.4	1037.4
Completed tackles per game (95% CI)	**625.2** *(619.8 to 630.7)*	620.6 *(609.8 to 631.6)*	650.8 *(641.5 to 660.1)*	602.8 *(594.1 to 611.7)*
Missed tackles per game (95% CI)	**75.7** *(75.0 to 76.3)*	77.0 *(75.7 to 78.4)*	70.3 *(69.3 to 71.3)*	80.1 *(78.9 to 81.3)*

Table 48: Number of tackles (complete and missed) by number of tacklers, tackle height, tackle direction and degree of tackle, and rates per 1000 tackles with 95% confidence interval and percentage of tackles recorded for level of competition (total, international rugby league, National Rugby League and National Youth Competition).

		Total tackles		International rugby league		National Rugby League		National Youth Competition
	No.	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*
Total	50019	1000.0 *(991.3 to 1008.8)*	12412[bc]	1000.0 *(982.6 to 1017.7)*	19523[ac]	1000.0 *(986.1 to 1014.1)*	18084[ab]	1000.0 *(985.5 to 1014.7)*
Number of tacklers								
1 Tackler	8877	177.5 *(173.8 to 181.2)*	2271	183.0 *(175.6 to 190.7)*	3304	169.2 *(163.6 to 175.1)*	3302	182.6 *(176.5 to 188.9)*
2 Tacklers	22884	457.5 *(451.6 to 463.5)*	5556[b]	447.6 *(436.0 to 459.6)*	8958[ac]	458.8 *(449.4 to 468.4)*	8370[b]	462.8 *(453.0 to 472.9)*
3 Tacklers	16372	327.3 *(322.3 to 332.4)*	4064[bc]	327.4 *(317.5 to 337.6)*	6753[ac]	345.9 *(337.7 to 354.2)*	5555[ab]	307.2 *(299.2 to 315.4)*
4 or more	1886	37.7 *(36.0 to 39.4)*	521[b]	42.0 *(38.5 to 45.7)*	508[ac]	26.0 *(23.9 to 28.4)*	857[b]	47.4 *(44.3 to 50.7)*
Tackle height								
Head/Neck	4499	46.9 *(45.5 to 48.3)*	1811[bc]	77.2 *(73.7 to 80.9)*	1213[ac]	31.8 *(30.1 to 33.6)*	1475[ab]	43.0 *(40.8 to 45.2)*
Shoulder	10755	112.1 *(110.0 to 114.2)*	2169[bc]	92.5 *(88.7 to 96.5)*	4582[ac]	120.1 *(116.7 to 123.7)*	4004[ab]	116.6 *(113.0 to 120.3)*
Mid torso	32788	341.8 *(338.1 to 345.5)*	6818[bc]	290.7 *(283.9 to 297.7)*	13828[ac]	362.5 *(356.5 to 368.6)*	12142[ab]	353.6 *(347.4 to 359.9)*
Hip / Thigh	34654	361.2 *(357.4 to 365.0)*	8627[bc]	367.8 *(360.1 to 375.7)*	13536[ac]	354.9 *(348.9 to 360.9)*	12491[ab]	363.8 *(357.4 to 370.2)*
Lower Legs	13241	138.0 *(135.7 to 140.4)*	4029[bc]	171.8 *(166.6 to 177.2)*	4985[ac]	130.7 *(127.1 to 134.4)*	4227[ab]	123.1 *(119.4 to 126.9)*
Degree of tackler position								
300°-330°	16199	176.7 *(174.0 to 179.4)*	4484[c]	190.0 *(184.6 to 195.7)*	6654[c]	185.0 *(180.6 to 189.5)*	5061[ab]	157.5 *(153.3 to 161.9)*
330°-360°	8549	93.2 *(91.3 to 95.2)*	3219[bc]	136.4 *(131.8 to 141.2)*	2788[ac]	77.5 *(74.7 to 80.5)*	2542[ab]	79.1 *(76.1 to 82.3)*
000°-030°	9970	108.7 *(106.6 to 110.9)*	2718[bc]	115.2 *(110.9 to 119.6)*	3792[ac]	105.5 *(102.1 to 108.9)*	3460[ab]	107.7 *(104.2 to 111.4)*
030°-060°	16890	184.2 *(181.5 to 187.0)*	3766[bc]	159.6 *(154.6 to 164.8)*	6581[a]	183.0 *(178.6 to 187.5)*	6543[a]	203.7 *(198.8 to 208.7)*
060°-300°	40071	437.1 *(432.8 to 441.4)*	9407[bc]	398.7 *(390.7 to 406.8)*	16145[ac]	449.0 *(442.1 to 456.0)*	14519[ab]	452.0 *(444.7 to 459.4)*

CI: Confidence Interval. No significant difference (*p*>0.05) than: (**a**)=International rugby league; (**b**)= National Rugby League; (**c**)= National Youth Competition.

More total tackles involved being tackled from the 060°-300° direction from the tackler than the 300°-330° (χ^2=10128, df=1), 330°-360° (χ^2=20437, df=1), 000°-030° (χ^2=18107, df=1), and 030°-060°(χ^2=519, df=1) directions (see Table 48). This was similar for international rugby league, National Rugby League and National Youth Competition levels of participation. There was a higher percentage of tackles involving contact from the 300°-330° degrees of the ball carrier at the international rugby league (19%) and National Rugby League (19%) levels of participation than the National Youth Competition (16%) and total (18%) tackles recorded, but these differences were not significant.

Match half, tackle number and field position of tackles

There were significantly more total tackles in the first, than the second half of matches (χ^2=8, df=1, p=0.004) (see Table 49), but not significantly more when compared to the international rugby league (χ^2=0, df=1, p=0.829), National Rugby League (χ^2=0, df=1, p=0.847) and National Youth Competition (χ^2=3, df=1, p=0.084) levels of participation. There were significantly more tackles recorded at the National Rugby League level of participation than international rugby league and National Youth Competition for the first (international rugby league: χ^2=9, df=1, p=0.003; National Youth Competition: χ^2=18, df=1) and second (international rugby league: χ^2=8, df=1, p=0.004; National Youth Competition: χ^2=39, df=1) halves of matches.

The percentage of completed sets of tackles (tackles 1 to 5) for total matches was 37% (95% CI: 36% to 37%). This was similar for the National Rugby League (37%, 37% to 38%) and National Youth Competition (35, 34% to 35%) but less than international rugby league competitions (39, 39% to 40%) (see Table 49). The National Youth Competition recorded significantly more missed tackles (15%) than international rugby league (13%; χ^2=276, df=1) and National Rugby League (9%; χ^2=209, df=1) levels of participation.

There were significantly more tackles in the defence than the attack side of the field for total matches (χ^2=373, df=1), international rugby league (χ^2=38, df=1), National Rugby League (χ^2=350, df=1) and National Youth Competition (χ^2=57, df=1) levels of participation (see Table 50). The most common field area for total tackles to occur was the defence 30-40 m zone recording 14% of total tackles. This was similar for the National Rugby League level of participation recording 16% of tackles in the 30-40 m defence zone while international rugby league recorded 14% of tackles in the defence 30-40 m and 20-30 m zones and National Youth Competition recorded 13% of tackles in the defence 20-30 m zone.

Player position, player type and player group as tackler

The hooker (no. 9) recorded more involvement in the tackle as the tackler (147; 95% CI 144 to 151 per 1,000 tackles, 15%) for total tackles recorded (see Table 51) than any other player position. This was similar for international rugby league (133; 127 to 139 per 1,000 tackles, 13%), National Rugby League (153; 148 to 158 per 1,000 tackles, 15%) and National Youth Competition (152; 146 to 157 per 1,000 tackles, 15%) levels of participation.

Forwards were significantly more involved in the tackle than backs for total (χ^2=4050, df=1), international rugby league (χ^2=864, df=1), National Rugby League (χ^2=1997, df=1) and National Youth Competition (χ^2=1246, df=1) levels of participation. Adjustables were significantly more involved in total tackles as the tackler than outside backs (χ^2=5630, df=1) and hit-up forwards (χ^2=3280, df=1) (see Table 51). This was similar for international rugby league, National Rugby League and National Youth Competition levels of competition.

Table 49: Number of tackles (complete and missed) by match half, tackle number and field position and rates per 1000 tackles with 95% confidence interval and percentage of tackles recorded for level of competition (total, international rugby league, National Rugby League and National Youth Competition).

		Total tackles		International rugby league		National Rugby League		National Youth Competition	
Match half		**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*
	First half	25334	506.5 *(500.3 to 512.8)*	6194[b]	499.0 *(486.8 to 511.6)*	9748[ac]	499.3 *(489.5 to 509.3)*	9158[b]	506.4 *(496.1 to 516.9)*
	Second half	24685[d]	493.5 *(487.4 to 499.7)*	6218[bc]	501.0 *(488.7 to 513.6)*	9775[ac]	500.7 *(490.9 to 510.7)*	8926[ab]	493.6 *(483.5 to 503.9)*
Tackle number									
	Tackle 0	883	17.7 *(16.5 to 18.9)*	172[c]	13.9 *(11.9 to 16.1)*	307[c]	15.7 *(14.1 to 17.6)*	404[ab]	22.3 *(20.3 to 24.6)*
	Tackle 1	12166	243.2 *(238.9 to 247.6)*	2895[c]	233.2 *(224.9 to 241.9)*	4835[ac]	247.7 *(240.8 to 254.7)*	4436[b]	245.3 *(238.2 to 252.6)*
	Tackle 2	10382	207.6 *(203.6 to 211.6)*	2532[bc]	204.0 *(196.2 to 212.1)*	4316[ac]	221.1 *(214.6 to 227.8)*	3534[ab]	195.4 *(189.1 to 202.0)*
	Tackle 3	8832	176.6 *(172.9 to 180.3)*	2183[bc]	175.9 *(168.7 to 183.4)*	3667[ac]	187.8 *(181.8 to 194.0)*	2982[ab]	164.9 *(159.1 to 170.9)*
	Tackle 4	6874	137.4 *(134.2 to 140.7)*	1769[c]	142.5 *(136.0 to 149.3)*	2731[c]	139.9 *(134.7 to 145.2)*	2374[ab]	131.3 *(126.1 to 136.7)*
	Tackle 5	4460	89.2 *(86.6 to 91.8)*	1135[c]	91.4 *(86.3 to 96.9)*	1789[c]	91.6 *(87.5 to 96.0)*	1536[ab]	84.9 *(80.8 to 89.3)*
	Tackle 6	217	4.3 *(3.8 to 5.0)*	69[c]	5.6 *(4.4 to 7.0)*	91[c]	4.7 *(3.8 to 5.7)*	57[ab]	3.2 *(2.4 to 4.1)*
	Incomplete	6205	124.1 *(121.0 to 127.2)*	1657[bc]	133.5 *(127.2 to 140.1)*	1787[ac]	91.5 *(87.4 to 95.9)*	2761[ab]	152.7 *(147.1 to 158.5)*
Field position									
Defence	In Goal	396	7.9 *(7.2 to 8.7)*	62[bc]	5.0 *(3.9 to 6.4)*	128[ac]	6.6 *(5.5 to 7.8)*	206[ab]	11.4 *(9.9 to 13.1)*
	0-10	1620	32.4 *(30.8 to 34.0)*	454[c]	36.6 *(33.4 to 40.1)*	638[c]	32.7 *(30.2 to 35.3)*	528[ab]	29.2 *(26.8 to 31.8)*
	Oct-20	5401	108.0 *(105.1 to 110.9)*	1205[b]	97.1 *(91.8 to 102.7)*	2428[ac]	124.4 *(119.5 to 129.4)*	1768[b]	97.8 *(93.3 to 102.4)*
	20-30	6513	130.2 *(127.1 to 133.4)*	1673	134.8 *(128.5 to 141.4)*	2440	125.0 *(120.1 to 130.0)*	2400	132.7 *(127.5 to 138.1)*
	30-40	7084	141.6 *(138.4 to 145.0)*	1680[bc]	135.4 *(129.0 to 142.0)*	3043[ac]	155.9 *(150.4 to 161.5)*	2361[ab]	130.6 *(125.4 to 135.9)*
	40-50	6156	123.1 *(120.0 to 126.2)*	1477[b]	119.0 *(113.1 to 125.2)*	2392[a]	122.5 *(117.7 to 127.5)*	2287	126.5 *(121.4 to 131.8)*
Attack	50-40	4720	94.4 *(91.7 to 97.1)*	1146[c]	92.3 *(87.1 to 97.8)*	1607[c]	82.3 *(78.4 to 86.4)*	1967[ab]	108.8 *(104.1 to 113.7)*
	40-30	3989	79.7 *(77.3 to 82.3)*	1014	81.7 *(76.8 to 86.9)*	1437	73.6 *(69.9 to 77.5)*	1538	85.0 *(80.9 to 89.4)*
	30-20	3956	79.1 *(76.7 to 81.6)*	946[b]	76.2 *(71.5 to 81.2)*	1565[ac]	80.2 *(76.3 to 84.2)*	1445[b]	79.9 *(75.9 to 84.1)*
	20-Oct	3754	75.1 *(72.7 to 77.5)*	1007[b]	81.1 *(76.3 to 86.3)*	1529[c]	78.3 *(74.5 to 82.3)*	1218[ab]	67.4 *(63.7 to 71.2)*
	10-0	5966	119.3 *(116.3 to 122.3)*	1590[bc]	128.1 *(122.0 to 134.6)*	2189[a]	112.1 *(107.5 to 116.9)*	2187[a]	120.9 *(116.0 to 126.1)*
	In Goal	464	9.3 *(8.5 to 10.2)*	158[bc]	12.7 *(10.9 to 14.9)*	127[ac]	6.5 *(5.5 to 7.7)*	179[ab]	9.9 *(8.5 to 11.5)*

CI: Confidence Interval. Significant difference ($p \leq 0.05$) than (**a**)=International rugby league; (**b**)= National Rugby League; (**c**)= National Youth Competition; (**d**) = first half.

Table 50: Number of tackles (complete and missed)as the tackler by player position, positional group and rates per 1000 tackles with 95% confidence interval and percentage of tackles recorded for level of competition (total, international rugby league, National Rugby League and national youth).

		Total tackles	International rugby league		National Rugby League		National Youth Competition	
Player Position	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*	**No.**	**Rate** *(95% CI)*
1. Fullback	1607	29.1 *(27.7 to 30.5)*	555[b]	38.8 *(35.7 to 42.2)*	287[ac]	14.1 *(12.5 to 15.8)*	765[b]	37.2 *(34.7 to 39.9)*
2. Wing	1292	23.4 *(22.1 to 24.7)*	472[bc]	33.0 *(30.2 to 36.2)*	460[ac]	22.5 *(20.6 to 24.7)*	360[ab]	17.5 *(15.8 to 19.4)*
3. Centre	2679	48.5 *(46.7 to 50.4)*	564[bc]	39.5 *(36.3 to 42.9)*	1095[a]	53.7 *(50.6 to 56.9)*	1020[a]	49.6 *(46.6 to 52.7)*
4. Centre	3895	70.5 *(68.3 to 72.7)*	1099[b]	76.9 *(72.5 to 81.6)*	1241[ac]	60.8 *(57.5 to 64.3)*	1555[b]	75.6 *(71.9 to 79.5)*
5. Wing	927	16.8 *(15.7 to 17.9)*	291[c]	20.4 *(18.2 to 22.8)*	396[c]	19.4 *(17.6 to 21.4)*	240[ab]	11.7 *(10.3 to 13.2)*
6. Stand Off	5891	106.6 *(103.9 to 109.4)*	1127[bc]	78.9 *(74.4 to 83.6)*	2347[a]	115.0 *(110.5 to 119.8)*	2417[a]	117.5 *(112.9 to 122.3)*
7. Half back	3858	69.8 *(67.7 to 72.1)*	1279[bc]	89.5 *(84.7 to 94.6)*	1184[ac]	58.0 *(54.8 to 61.4)*	1395[ab]	67.8 *(64.4 to 71.5)*
8. Prop	4824	87.3 *(84.9 to 89.8)*	1380[bc]	96.6 *(91.6 to 101.8)*	1659[ac]	81.3 *(77.5 to 85.3)*	1785[ab]	86.8 *(82.9 to 90.9)*
9. Hooker	8138	147.3 *(144.1 to 150.5)*	1904[bc]	133.3 *(127.4 to 139.4)*	3119[a]	152.9 *(147.6 to 158.3)*	3115[a]	151.5 *(146.2 to 156.9)*
10. Prop	4986	90.2 *(87.8 to 92.8)*	1514[bc]	106.0 *(100.8 to 111.4)*	1567[ac]	76.8 *(73.1 to 80.7)*	1905[ab]	92.6 *(88.6 to 96.9)*
11. Second row	3997	72.3 *(70.1 to 74.6)*	1134[c]	79.4 *(74.9 to 84.1)*	1663[c]	81.5 *(77.7 to 85.5)*	1200[ab]	58.4 *(55.1 to 61.7)*
12. Second row	6654	120.4 *(117.6 to 123.3)*	1495[b]	104.6 *(99.5 to 110.1)*	2833[ac]	138.8 *(133.8 to 144.1)*	2326[b]	113.1 *(108.6 to 117.8)*
13. Loose Forward	6509	117.8 *(115.0 to 120.7)*	1474[bc]	103.2 *(98.0 to 108.6)*	2553[a]	125.1 *(120.4 to 130.1)*	2482[a]	120.7 *(116.0 to 125.5)*
Forwards	35108	635.4 *(628.7 to 642.0)*	8901[cd]	623.0 *(610.2 to 636.0)*	13394[cd]	656.4 *(645.4 to 667.7)*	12813[bd]	623.0 *(612.4 to 633.9)*
Backs	20149	364.6 *(359.6 to 369.7)*	5387[bc]	377.0 *(367.1 to 387.2)*	7010[ac]	343.6 *(335.6 to 351.7)*	7752[ab]	377.0 *(368.7 to 385.4)*
Outside Backs	10400[dg]	188.2 *(184.6 to 191.9)*	2981[bcdg]	208.6 *(201.3 to 216.3)*	3479[acdg]	170.5 *(164.9 to 176.3)*	3940[abdg]	191.6 *(185.7 to 197.7)*
Adjustables	24396[ed]	441.5 *(436.0 to 447.1)*	5784[bced]	404.8 *(394.5 to 415.4)*	9203[aed]	451.0 *(441.9 to 460.3)*	9409[aed]	457.5 *(448.4 to 466.9)*
Hit Up Forwards	20461[ef]	370.3 *(365.2 to 375.4)*	5523[bcef]	386.5 *(376.5 to 396.9)*	7722[acef]	378.5 *(370.1 to 387.0)*	7216[abef]	350.9 *(342.9 to 359.1)*

CI: Confidence Interval. Significant difference ($p \leq 0.05$) than: (**a**)=International rugby league; (**b**)= National Rugby League; (**c**)= National Youth Competition; (**d**)= Backs; (**e**)= Outside Backs; (**f**)= Adjustables; (**g**)= Hit Up Forwards.

Table 51: Number of tackles (complete and missed) as the ball carrier by player position, positional group and rates per 1000 tackles with 95% confidence interval and percentage of tackles recorded for level of competition (total, international rugby league, National Rugby League and National Youth Competition).

		Total tackles	International rugby league		National Rugby League		National Youth Competition	
Player Position	**No.**	**Rate (95% CI)**	**No.**	**Rate (95% CI)**	**No.**	**Rate (95% CI)**	**No.**	**Rate (95% CI)**
1. Fullback	2649	53.0 *(51.0 to 55.0)*	670	54.0 *(50.0 to 58.2)*	924[c]	47.3 *(44.4 to 50.5)*	1055[b]	112.5 *(105.9 to 119.5)*
2. Wing	2180	43.6 *(41.8 to 45.5)*	583[c]	47.0 *(43.3 to 50.9)*	827	42.4 *(39.6 to 45.3)*	770[a]	82.1 *(76.5 to 88.1)*
3. Centre	1996	39.9 *(38.2 to 41.7)*	486	39.2 *(35.8 to 42.8)*	740	37.9 *(35.3 to 40.7)*	770	82.1 *(76.5 to 88.1)*
4. Centre	2049	41.0 *(39.2 to 42.8)*	568[c]	45.8 *(42.1 to 49.7)*	801[c]	41.0 *(38.3 to 44.0)*	680[ab]	72.5 *(67.3 to 78.2)*
5. Wing	2282	45.6 *(43.8 to 47.5)*	520[c]	41.9 *(38.4 to 45.7)*	839[c]	43.0 *(40.2 to 46.0)*	923[ab]	98.5 *(92.3 to 105.0)*
6. Stand Off	1350	27.0 *(25.6 to 28.5)*	378[c]	30.5 *(27.5 to 33.7)*	545[c]	27.9 *(25.7 to 30.4)*	427[ab]	45.5 *(41.4 to 50.1)*
7. Half back	1212	24.2 *(22.9 to 25.6)*	341[b]	27.5 *(24.7 to 30.5)*	346[ac]	17.7 *(16.0 to 19.7)*	525[b]	56.0 *(51.4 to 61.0)*
8. Prop	2365	47.3 *(45.4 to 49.2)*	574[c]	46.2 *(42.6 to 50.2)*	806[c]	41.3 *(38.5 to 44.2)*	985[ab]	105.1 *(98.7 to 111.8)*
9. Hooker	1220	24.4 *(23.1 to 25.8)*	276	22.2 *(19.8 to 25.0)*	479	24.5 *(22.4 to 26.8)*	465	49.6 *(45.3 to 54.3)*
10. Prop	2108	42.1 *(40.4 to 44.0)*	576[b]	46.4 *(42.8 to 50.4)*	727[ac]	37.2 *(34.6 to 40.0)*	805[b]	85.9 *(80.1 to 92.0)*
11. Second row	2325	46.5 *(44.6 to 48.4)*	595[b]	47.9 *(44.2 to 51.9)*	1110[ac]	56.9 *(53.6 to 60.3)*	620[b]	66.1 *(61.1 to 71.5)*
12. Second row	2040	40.8 *(39.1 to 42.6)*	471[b]	37.9 *(34.7 to 41.5)*	839[ac]	43.0 *(40.2 to 46.0)*	730[b]	77.9 *(72.4 to 83.7)*
13. Loose Forward	1606	32.1 *(30.6 to 33.7)*	463[b]	37.3 *(34.1 to 40.9)*	523[ac]	26.8 *(24.6 to 29.2)*	620[b]	66.1 *(61.1 to 71.5)*
Forwards	11664[e]	233.2 *(229.0 to 237.5)*	2955[de]	238.1 *(229.6 to 246.8)*	4484[cd]	229.7 *(223.1 to 236.5)*	4225[abd]	450.7 *(437.3 to 464.5)*
Backs	13718	274.3 *(269.7 to 278.9)*	35462	285.7 *(276.4 to 295.3)*	5022[a]	257.2 *(250.2 to 264.4)*	5150	549.3 *(534.5 to 564.5)*
Outside Backs	11156	439.5 *(431.4 to 447.8)*	2827[fg]	434.9 *(419.1 to 451.2)*	4131[fg]	434.6 *(421.5 to 448.0)*	4198[fg]	447.8 *(434.4 to 461.5)*
Adjustables	5388	212.3 *(206.7 to 218.0)*	1458[bcef]	224.3 *(213.1 to 236.1)*	1893[aeg]	199.1 *(190.4 to 208.3)*	2037[afg]	217.3 *(208.0 to 226.9)*
Hit Up Forwards	8838	348.2 *(341.0 to 355.5)*	2216[cef]	340.9 *(327.0 to 355.4)*	3482[ceg]	366.3 *(354.3 to 378.7)*	3140[abef]	334.9 *(323.4 to 346.9)*

CI: Confidence Interval. Significant difference ($p \leq 0.05$) than: (**a**)=International rugby league; (**b**)= National Rugby League; (**c**)= National Youth Competition; (**d**)= Backs; (**e**)= Outside Backs; (**f**)= Adjustables; (**g**)= Hit Up Forwards.

Player position, player type and player group as ball carrier

The Fullback (No. 1) recorded more tackles as the ball carrier (53; 51 to 55 per 1,000 tackles, 10%) for total tackles (see Table 5) than any other player position. This was similar for international rugby league (103; 96 to 111 per 1,000 tackles, 10%) and National Youth Competition (113; 106 to 120 per 1,000 tackles, 11%) levels of participation. The second row forward (No. 11) recorded the most tackles (117; 110 to 124 per 1,000 tackles, 12%) as the ball carrier than any other player position for the National Rugby League level of participation, but these differences were not significant.

Backs were tackled significantly more than forwards for total (χ^2=166, df=1), international rugby league (χ^2=54, df=1), National Rugby League (χ^2=30, df=1) and National Youth Competition (χ^2=91, df=1) levels of participation. When comparing positional groups for tackled as the ball carrier the outside backs were tackled significantly more than adjustables (χ^2=2011, df=1) and hit-up forwards (χ^2=269, df=1). This was similar for international rugby league, National Rugby League and National Youth Competition levels of competition.

Discussion

This study undertook to describe the nature, height, site, field location and direction of tackles seen in professional rugby league matches. As shown by this study the tackle in rugby league most commonly involved two tacklers with contact to the hip and thigh region from behind the ball carrier. There were more tackles in the first than the second half of matches and in the defensive 30-40 m zone than other parts of the rugby league field. Forwards were more commonly involved in the tackle than backs as the tackler with the hooker recording the most tackles. Backs were more commonly involved in the tackle as the ball carrier than forwards with the fullback more commonly tackled as the ball carrier than other playing positions.

Seen as arguably the most important skill in rugby league, the tackle is necessary for playing success and is dependent on players tackling ability, their capacity to tolerate the associated physical collisions and the ability to ‘win’ the tackle contest.[94] Greater playing experience is associated with a better tackling technique; players with over 150 matches recorded superior tackling technique than players with less than 150 matches in the National Rugby League.[105] Additionally, players with a greater tackling technique were involved in more tackle events per match than players with poorer tackling technique.[105] No studies to date have reported on the tackle at the amateur, junior and semi-professional/sub-elite level of participation. These studies would assist in further understanding the tackle in rugby league and whether playing experience, tackle training and the anthropometric and physiological characteristics have the reported effects found at professional levels of participation.

Although more tackles were recorded in the second than the first half of matches during international rugby league and National Rugby League levels of participation, this differed with the National Youth Competition level of participation. This finding may be reflective of the participation level but there are no published studies on the characteristics of the tackle at the different levels of participation to enable further comparisons to be undertaken. Further studies comparing the tackle at the different levels of participation are warranted.

A possible explanation for the difference in the number of tackles by match halves may be the effects of fatigue on the National Youth Competition players. Players at this level of participation are under the age of 20 and their physiological capacities may not be fully developed. In a study[75] comparing junior and senior level rugby league participants there was a progressive improvement in the physiological capacities of rugby league participants as the playing level increased. This progressive improvement may be reflected in the differences reported in our study between the number of tackles recorded in the first and second half of matches between National Youth Competition and National Rugby League and International rugby league levels of participation. More studies are warranted on the effects of level of participation on the characteristics of tackles.

Although our study reported a higher proportion of tackle involvement by players than previously reported,[105] the differences may be in the methodology utilised in this study. Gabbett & Ryan (2009) reported an average of 24 (range 7 to 39) tackle events per player per match compared to our study that reports an average of 54 (range 35 to 73) tackle events per player per match. Gabbett and Ryan's (2009) review used only one of the teams tackle events per match while our study reported both teams tackle events. When the numbers of players are taken into account the average tackle events per player (27 range 17 to 36) is similar to the previous study.[105]

Forwards were more commonly involved in tackle events than backs but when viewed in player groups, adjustables were involved in more tackle events than outside backs and hit-up forwards. When viewed by participation level, hit-up forwards recorded more involvement in tackle events at International rugby league and National Rugby League levels of participation which was similar to the findings of a previous study.[105] Hit-up forwards are predominantly in the middle of the defensive line and middle of the field.[105] The field space in which this group work is limited and they often perform tackles with the assistance of multiple defenders. [105] Additionally, as previously reported, players with the higher playing experience and greater tackling technique are involved in tackle events more often.[105] No studies have been undertaken at other levels of rugby league participation to enable further analysis to be completed. As a result of this further studies are warranted to explore the tackle by player positions and positional groups at junior, amateur, semi-professional/sub-elite levels of participation are warranted.

The hooker (no. 9) was the most frequently player involved in the tackle as the tackler. Time-motion studies have reported that the hooker covering a greater total distance during matches than any other player position.[181] The hooker plays an important role in ball distribution to support players, supports the ball carrier in the attacking phase and defends in the middle of the ruck.[181] The high involvement of the hooker in the defensive phases of match play often results in them being more directly in a position to tackle than any other player position.[181]

The fullback (no. 1) was the most commonly tackled player as the ball carrier over the duration of the study. Backs were more commonly tackled as the ball carrier and this was reflected in the positional groups with outside backs being tackled more than adjustables and hit-up forwards. Outside backs are typically required to perform more attacking plays in matches than defending. Interestingly more tackles occurred in the defensive than the attacking ends of the playing field with the 30-40 m zone the most common area to be tackled in. This may be reflective of the nature of rugby league as teams endeavour to defend this part of the field as the opposition tries to attack towards scoring a try.

Conclusion

The nature of tackles for professional rugby league players varied for ball carrier and tackler as well as by player position. Tackles occurred more in the defence 30-40 m zone, with contact to the mid-torso region, in the ball carriers blind vision and with two or more tacklers in the first half of matches. Coaches should focus on getting players to practice correct technique during tackling with two or more tacklers and when tackling in the ball carriers blind vision area.

CHAPTER 10: NATURE OF TACKLES THAT RESULT IN INJURY IN PROFESSIONAL RUGBY LEAGUE: A CASE STUDY

This chapter comprises the following paper submitted to *Research in Sports Medicine.*

Reference

King, DA., Hume, & Clark, T. Nature of tackles that result in injury in professional rugby league. *Submitted to Research in Sports Medicine.*

Author contributions

King, D. 82%; Hume, P. 15%; Clark, T. 3%

Overview

A total of 31,655 tackles in 48 professional rugby league matches were coded from video for height and direction of tackle on the ball carrier. Injuries were recorded by team medical staff for injury date, time, site, type, mechanism, severity and for player position. Tackle-related injuries were most frequently the result of two tacklers being involved in tackling the ball-carrier from the side at shoulder or mid torso body levels. The ball carrier had a higher injury rate when tackled from behind their visual field at shoulder height and in the fourth quarter of matches. Tacklers had a higher risk of injury when tackling from the side of the ball carrier, as the first tackler, and in the third quarter of matches. Coaches should focus on practicing correct technique during tackling with two or more tacklers and when tackling in the ball carriers blind vision area.

Introduction

Originating in the north of England in the 1890's, rugby league is a contact sport played internationally[87, 159] The game is played over two halves of 40 minutes at amateur, sub-elite/semi-professional or elite/professional levels of participation.[159] Players compete in a challenging contest that involves bouts of high-intensity activities (e.g. sprinting, running, passing, and tackling) separated by short bouts of low-intensity activities (e.g. standing, walking, jogging).[78] The physiological demands of the game are complex and require players to have highly developed speed, agility, muscular strength and power, and maximal aerobic capacity.[104]

Research on tackles in rugby league has shown that: (1) Fast defensive line speed reduces tackling proficiency;[100] (2) Anthropometric (stature, body mass, skinfold thickness, somatotype) and physiological (fast acceleration and change-of-direction speed) factors are associated with tackling ability;[94] and (3) There is a direct relationship between physiological capacities and fatigue-induced decrements in tackling technique.[93] Dominance of the tackle contest, the ability to tolerate physical collisions that occur in the tackle, and tackling ability are important for success in rugby league.[100] Between 46-90% of injuries are tackle-related in rugby league matches.[78] Despite this high percentage there has been no published study examining the nature of rugby league tackles that result in injury. However, studies on rugby union tackles[66, 212] showed injuries to the ball carrier were most frequently to the head-neck region from high or middle body level tackles from the front or side. Tacklers had a higher injury rate when approaching the ball carrier from behind than when approaching from the front or side and when making low tackles. Similar analyses are needed to elucidate the nature of tackle-related injuries in rugby league. Therefore the aim of this study was to examine the nature of rugby league tackles associated with injuries for professional players.

Methods

Participants

A single professional rugby league team was followed for a total of 48 matches throughout 2007 and 2008. Matches were played at locations in Australia and in New Zealand. All matches were two halves of 40 minutes with an overall match exposure of 830 playing hours. The team was involved in 24 competition matches over 26 weeks each year. Teams making the top eight on the competition ladder compete in the MacIntyre finals competition system and can compete in a further six matches to reach the Grand Final. The team under study did not make the top eight in both years of the competition under study. All other teams involved in the competition were invited to partake in the study with only one team agreeing to partake and allowing access to the injury data.

Ethical consent

Ethical consent for the research was obtained from the Auckland University of Technology (AUT) University Human Ethics Committee. Consent for access to individual player injury data was obtained from the participating professional rugby league club. Informed consent from the injured players was not obtained as they had a club contract that allowed analysis of their data. All recordings of matches were available through international television coverage.

Injury data and definitions for the nature of injury

A prospective observational cohort design was undertaken. All injuries that occurred in the team were assessed and recorded by the team medical staff (doctor, physiotherapist or rehabilitation coordinator). The injury data were collated by the rehabilitation coordinator of the team under study. Injury date, player position,[78] time of injury, injury site and type,[77, 148] injury mechanism and injury severity (days unavailable for selection) were recorded.[77, 134] Definitions for injury data included:

a. *Missed match injuries:* A tackle that resulted in an injury that rendered the player unavailable for selection in the next match.[155]
b. *Injury rate:* The number of injuries per 10,000 tackle events and per 1,000 match hours[155] where player match exposure was on average 830 hours.
c. *Injury mechanism:* The injury mechanisms of all recorded injuries were reviewed by one auditor to identify whether they met the definition of a rugby league tackle (see later definitions).
d. *Injury severity:* Classified as either transient (no matches missed), minor (one match missed), moderate (two to four matches missed), or major (five or more matches missed).[77, 134, 155]

Video data and definitions of tackles and related characteristics

Video analyses of televised coverage of matches allowed documentation of the nature of rugby league tackles associated with injuries. One analyst used *Sports Performer*© (Premier Concepts Pty Ltd, Sydney, Australia; http://www.sportsperformer.com.au) to code tackles noting the match date, venue, player number, number of tackles in the set, number of tacklers involved in the tackle, field location where the tackle occurred and whether the injured player was a ball carrier being tackled or was the tackler tackling a ball carrier. Slow time motion replay and *ImageJ* (http://rsb.info.nih.gov/ij/) were used to measure the tackle approach or orientation of the tackler to the ball carrier. Definitions for tackles, tackle approach or orientation and related characteristics included:

a. *Tackle:* A tackle occurs when the ball carrier is held by one or more of the opposing players and either the ball or hand of the arm holding the ball makes contact with the ground or the ball carriers cannot make any further progress. Section 11 of the International Laws of Rugby League was used to define a tackle in regards to how the ball carrier was held by the tackler(s) to complete the tackle.[3, 117]
b. *Missed tackle:* Any unsuccessful attempt to complete a tackle where the tackler/defender has made contact with the ball carrier and they have broken from the tackle before it is completed.[3, 122]
c. *Tackle number:* The team in possession of the ball was allowed five successive plays of the ball. The ball was handed over to the opposition after the fifth play of the ball or when the team in possession: (1) Is tackled a sixth time, (2) Commits an accidental breach (i.e. knock on, forward pass and possession changes team resulting in a 'zero tackle'); (3)

Has a player held-up and unable to ground the ball in the opponents' in-goal; or (4) Kicks the ball directly into touch on the full.

d. *Tackle height:* Classified according to five different regions of the body: (1) Lower legs – from the player's knees to their toes; (2) Hip and thigh – from above the player's knees to the player's hip level; (3) Mid-torso – from above the player's hip level to the level of the player's arm pit; (4) Shoulder – from the player's arm pit to the level of the shoulder including the arm; and (5) Head and neck – above the shoulder with any connection with the head and/or neck during the course of the tackle.[212] When the injured player was the ball carrier, all tacklers involved in the tackle were recorded for tackle height. When the injured player was the tackler, only the injured player was recorded for tackle height.

e. *Tackle direction or orientation:* The tackle direction used in this study was identical to previously published studies.[106, 212] The tackle direction was classified as: (1) Tackler being head-on to the ball carrier (0°); (2) Tackler being in the ball carrier's side vision (left side: 330° to 359°; right side 001° to 030°); (3) Tackler being in the ball carrier's peripheral vision (left side: 300° to 329°; right side: 031° to 060°) or in the ball carrier's blind vision (between 061° to 299°) when the tackle occurred (see Figure 5).[106, 212] When the injured player was the ball carrier all tacklers involved in the tackle were recorded for tackle direction or orientation relative to the ball carrier's view. When the injured player was the tackler, only the injured player was recorded for tackle direction or orientation.

f. *Field position:* This was classified as either defence (the side in which the team must defend their own in-goal area in order to stop the opposition team scoring a try), or attack (the side in which the team must enter to score a try in the opposition in-goal area) halves of the field. A regulation field length is 100 metres with a maximum in-goal size of eight metres in depth.[3] The field was divided into 10 metre sections marked from 0 (goal-line) to 50 (half-way) for both halves of the field.

Statistical analyses

Video data were cross-linked with injury data by one analyst using a Microsoft Excel spreadsheet by matching player name, date and time of play. Data were analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA) statistical software. Injury rates per 10,000 tackle events and per 1,000 match hours were calculated.[135, 136] Data were reported as means and standard deviations with 95% confidence intervals (CI) where appropriate.[140, 240] Significant p values reported in the text are less than 0.001 if they are not specifically stated. To compare between tackle-related injury numbers and rates and rugby league match exposure characteristics in 2007 versus 2008, risk ratios (RR) were used. For comparisons of ball carriers versus tacklers for number of tacklers, tackle height, degree of tackle approach, injury site, region, type and severity of injury, player position, field position, number of tackles, and match period, risk ratios (RR) were again used.

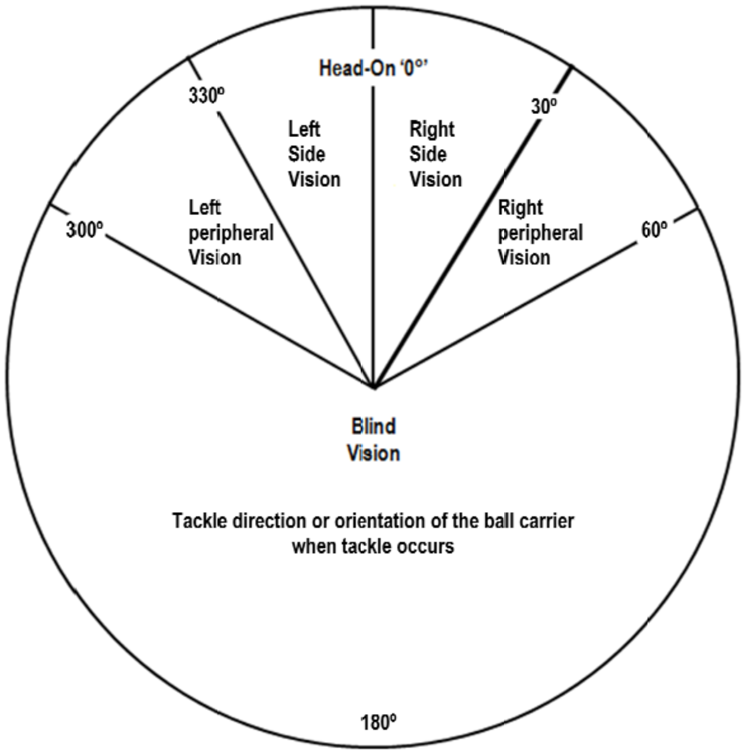

Figure 5: Tackle direction or orientation.

Results

Number of tackles

Throughout the 48 matches there were 31,655 tackles, representing 590 ±50 (mean ±SD) completed tackles and 67 ±14 missed tackles per match. There were no significant differences ($\chi 2$=2, df=1, p=0.128) in the number of tackles made by the team under study (n=15,963; 298 ±31 completed and 34 ±10 missed tackles per match) compared with any of the opposition teams (n=15,692; 291 ±37 completed and 34 ±13 missed tackles per match). The hooker recorded more tackles per match than any other playing position (26.3 ±10.2 completed and 3.3 ±1.2 missed tackles per match) over the duration of the study (see Table 52).

Table 52: Mean and standard deviation number of tackles completed, missed and total for match by player position and player group for 2007 and 2008 and combined years.

	2007			2008			Combined		
	Completed Mean ±SD	Missed Mean ±SD	Total Mean ±SD	Completed Mean ±SD	Missed Mean ±SD	Total Mean ±SD	Completed Mean ±SD	Missed Mean ±SD	Total Mean ±SD
Prop	22.2, 5.9	2.0, 0.7	24.1, 5.9	23.4, 4.4	1.6, 0.7	25.2, 3.9	22.7, 5.2	1.9, 0.8	24.6, 5.1
Hooker	30.2, 7.5	3.1, 1.0	33.2, 7.9	28.6, 12.8	3.5, 1.5	32.0, 11.9	29.3, 10.2	3.3, 1.2	32.6, 9.7
Second row	21.7, 8.5	2.2, 1.2	23.9, 9.2	28.1, 4.6	2.1, 1.4	30.2, 3.9	24.3, 7.7	2.2, 1.2	26.4, 8.0
Lock Forward	27.7, 4.7	2.0, 1.1	29.8, 5.4	22.1, 12.0	1.4, 1.6	23.4, 13.4	25.2, 8.8	1.7, 1.4	26.9, 9.9
Half Back	12.5, 6.3	4.3, 2.4	16.9, 7.1	16.5, 6.1	2.0, 1.4	18.5, 5.1	14.3, 6.2	3.3, 2.3	17.6, 6.0
Stand Off	18.9, 4.0	2.6, 0.6	21.5, 4.2	20.8, 4.0	2.0, 0.5	22.8, 3.6	19.5, 3.9	2.4, 0.6	21.9, 3.6
Centre	12.3, 3.3	1.7, 0.8	13.9, 4.0	15.5, 9.8	1.9, 0.9	17.4, 10.0	14.2, 7.7	1.8, 0.8	16.0, 8.0
Wing	4.6, 1.2	1.7, 0.3	6.3, 1.1	3.9, 1.0	1.7, 0.7	5.7, 0.8	4.2, 1.1	1.7, 0.5	6.0, 1.0
Fullback	6.5, 2.1	3.7, 2.4	10.2, 2.5	5.4, 0.5	2.0, 0.9	7.3, 0.4	6.0, 1.7	3.0, 2.0	9.1, 2.4
Forward	24.4, 7.3	2.2, 1.0	26.6, 7.8	25.6, 8.8	2.9, 1.5	27.7, 9.0	24.9, 7.9	2.2, 1.2	27.1, 8.3
Back	12.0, 6.5	2.8, 1.7	14.8, 6.9	12.6, 8.7	1.9, 0.8	14.5, 8.7	12.3, 7.5	2.4, 2.3	14.6, 7.7

SD: Standard Deviation

Number and rate of tackle-related injuries

There were 266 injuries recorded over the duration of the study. The majority of injuries (n=249; 94%) were tackle-related injuries (117 injuries to the tackler and 132 injuries to the ball carrier) (see Table 53). Total tackle-related injury rate was 300; 265 to 340 per 1,000 match hours (79; 70 to 89 per 10,000 tackles) with significant differences observed between the different years for tackle-related injury rates (2007: 340 per 1,000 match hours (89 per 10,000 tackle events); 2008: 260 per 1,000 match hours (69 per 10,000 tackle events); RR: 1.3 [1.0-1.7]; *p*=0.037).

Table 53: Tackle-related injury numbers and rates with 95% confidence intervals (95% CI) and rugby league match exposure characteristics over the 48 matches. Risk ratios are for comparisons of 2007 versus 2008.

	2007	2008	Total	Risk Ratio 2007 vs. 2008 RR *(95% CI)*	p
Total number of tackle-related injuries per match (95% CI)	5.9 *(5.0-6.9)*	4.5 *(3.7-5.4)*	**5.2** *(4.6-5.9)*	1.3 *(0.4-4.5)*	0.664
Tackle-related injuries	141	108	**249**	1.3 *(1.0-1.6)*	0.037
Number of matches played	24	24	**48**		
Match exposure hours	415	415	**830**		
Exposure hours per injury (95% CI)	2.9 *(2.5-3.5)*	3.8 *(3.2-4.6)*	**3.3** *(2.9-3.8)*	0.8 *(0.2-3.5)*	0.728
Tackle-related injury rates per 1,000 match hours (95% CI)	340 *(288-401)*	260 *(216-314)*	**300** *(265-340)*	1.3 *(1.1-1.5)*	0.001
Tackle-related injury rates per 10,000 tackle events (95% CI)	4.5 *(3.8-5.3)*	3.4 *(2.8-4.1)*	**249** *(6.9-8.9)*	1.3 *(1.0-1.6)*	0.037

Tackle-related injuries analysed by number of tacklers, tackle height, and degree of tackle approach

The ball carrier accounted for slightly more than half (53%) of the total tackle-related injuries (see Table 54). The tackle-related injury rate for ball carriers was significantly higher when two tacklers in total completed the tackle compared with one (RR: 2.0 [1.3-3.0]; *p*=0.002), three (RR: 2.3 [1.6-3.3]; *p*=0.025) and four or more tacklers (RR: 11.9 [6.0-23.5]). Injuries to the tackler accounted for 47% of the tackle-related injuries (see Table 57). The first tackler to effect the tackle sustained significantly more injuries than the third (RR: 6.3 [3.2-12.7]), fourth or subsequent (RR: 19.0 [6.0-60.4]) tacklers involved. There were significantly more injuries were recorded in the first tackle by the tackler (RR: 1.9 [1.2-2.9]) than the ball carrier. The ball carrier recorded significantly more injuries on the third tackle than the tackler (RR: 4.1 [2.0-8.5]; *p*<0.001). The ball carrier recorded more tackle injuries than the tackler when contact was made with the head and neck (RR: 5.7 [3.0-10.8]), shoulder (RR: 1.5 [1.1-2.2], *p*=0.023), mid torso (RR: 1.9 [1.2-2.8], *p*=0.003) and hip/thigh (RR: 1.8 [1.0-3.0], *p*=0.036).

Table 54: Number of tacklers, tackle height and degree of tackle approach for tackle-related injury numbers, percentages and rates per 10,000 tackle events and per 1,000 match hours with 95% confidence intervals (95% CI) for ball carrier and tackler positions. Risk ratios are for comparisons of ball carrier versus tackler.

		Ball carrier injury rate per				Tackler injury rate per			Risk Ratio ball carrier vs. tackler	
		10,000 tackle events	1,000 match hours			10,000 tackle events	1,000 match hours			
	No.	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**No.**	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**RR** *(95% CI)*	**p**
Total	132	84 *(71-100)*	159 *(134-189)*	53	117	73 *(61-88)*	141 *(118-169)*	47	1.1 *(0.9-1.4)*	0.342
Number of tacklers										
1	30	191 *(13-27)*	36 *(25-52)*	23	57[a]	36 *(28-46)*	69 *(53-89)*	49	0.5 *(0.3-0.8)*	0.004
2	59	38 *(29-49)*	71 *(55-92)*	45	48	30 *(23-40)*	58 *(44-77)*	41	1.2 *(0.9-1.8)*	0.288
3	37	24 *(17-33)*	45 *(32-62)*	28	9[a]	6 *(3-11)*	11 *(6-21)*	8	4.1 *(2.0-8.5)*	<0.001
4 or more	6	4 *(2-9)*	7 *(3-16)*	5	3	2 *(1-6)*	4 *(1-12)*	3	2.0 *(0.5-8.0)*	0.317
Tackle height										
Head/Neck	63	40 *(31-51)*	76 *(59-97)*	27	11[a]	7 *(4-12)*	13 *(7-24)*	9	5.7 *(3.0-10.8)*	<0.001
Shoulder	68	43 *(34-55)*	82 *(65-104)*	29	44[a]	28 *(21-37)*	53 *(40-71)*	38	1.5 *(1.1-2.2)*	0.023
Mid torso	63	40 *(31-51)*	76 *(59-97)*	27	34[a]	21 *(15-30)*	41 *(29-57)*	29	1.9 *(1.2-2.8)*	0.003
Hip/Thigh	37	24 *(17-33)*	45 *(32-62)*	16	21[a]	13 *(9-20)*	25 *(17-39)*	18	1.8 *(1.0-3.0)*	0.036
Lower legs	7	5 *(2-9)*	8 *(4-18)*	3	7	4 *(2-9)*	8 *(4-18)*	6	1.0 *(0.4-2.8)*	1
Degree of tackle approach										
300-330	49	31 *(24-41)*	59 *(45-78)*	25	19[a]	12 *(8-19)*	23 *(15-36)*	16	2.6 *(1.5-4.3)*	<0.001
330-360	20	13 *(8-20)*	24 *(16-37)*	10	13	8 *(5-14)*	16*(9-27)*	11	1.5 *(0.8-3.1)*	0.223
0-30	25	16 *(11-24)*	30 *(20-45)*	13	13	8 *(5-14)*	16 *(9-27)*	11	1.9 *(1.0-3.7)*	0.052
30-60	44	28 *(21-38)*	53 *(40-71)*	22	22[a]	14 *(9-21)*	27 *(18-40)*	19	2.0 *(1.2-3.3)*	0.007
60-300	59	38 *(29-49)*	71 *(55-92)*	30	50	31 *(24-41)*	60 *(46-80)*	43	1.2 *(0.8-1.7)*	0.389

Significant difference (p≤0.05) from (**a**)=ball carrier

Tackle-related injuries by injury site, type and severity

The quadriceps was the most commonly recorded injury site to the ball carrier (see Table 55). The ball carrier recorded significantly more injuries to the lower than the upper limb (RR: 6.1 [3.5-10.6]; *p*<0.001), head and neck (RR: 4.0 [2.5-6.5]) and chest/back (RR: 7.1 [3.9-12.9]). The tackler recorded significantly more upper limb injuries than the lower limb (RR: 1.8 [1.2-2.7]; *p*=0.008), head and neck (RR: 3.2 [1.9-5.3]) and chest/back (RR: 5.7 [2.9-11.1]). The most common injury type recorded over the study period was bruise/contusions (105 per 1,000 match hours; 28 per 10,000 tackle events) for both the ball carrier and tackler (see Table 58). Strain's (75 per 1,000 match hours; 20 per 10,000 tackle events), sprains (59 per 1,000 match hours; 16 per 10,000 tackle events) and concussions (21 per 1,000 match hours; 5 per 10,000 tackle events) were less common. Transient injuries (242 per 1,000 match hours; 64 per 10,000 tackle events) accounted for 81% of the total tackle-related injuries while mild (35 per 1,000 match hours; 9 per 10,000 tackle events; 12%), moderate (5 per 1,000 match hours; 1 per 10,000 tackle events; 2%) and major (18 per 1,000 match hours; 5 per 10,000 tackle events; 6%) injuries were less common.

Table 55: Injury site, region, type and severity for tackle-related injury numbers, percentages and rates per 10,000 tackle events and per 1,000 match hours with 95% confidence intervals (95% CI) for ball carrier and tackler positions. Risk ratios are for comparisons of ball carrier versus tackler.

		Ball carrier injury rate per 10,000 tackle events	Ball carrier injury rate per 1,000 match hours			Tackler injury rate per 10,000 tackle events	Tackler injury rate per 1,000 match hours		Risk Ratio ball carrier vs. tackler	
	No.	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**No.**	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**RR** *(95% CI)*	**p**
Injury site										
Head	12	8 *(4-14)*	15 *(8-26)*	9	14	9 *(5-15)*	17 *(10-29)*	12	0.9 *(0.4-1.8)*	0.695
Eye	1	1 *(0-5)*	1 *(0-9)*	1	0	0 -	0-	0	-	-
Nose	1	1 *(0-5)*	1 *(0-9)*	1	0	0 -	0-	0	-	-
Mouth	3	2 *(1-6)*	4 *(1-11)*	2	0	0 -	0-	0	-	-
Neck	4	3 *(1-7)*	5 *(2-13)*	3	4	3 *(1-7)*	5 *(2-13)*	3	1.0 *(0.3-4.0)*	1
Shoulder	9	6 *(3-11)*	11 *(6-21)*	7	18	11 *(7-18)*	22 *(14-34)*	15	0.5 *(0.2-1.1)*	0.083
Upper arm	3	2 *(1-6)*	4 *(1-11)*	2	7	4 *(2-9)*	8 *(4-18)*	6	0.4 *(0.1-1.7)*	0.206
Elbow	0	0.0 -	0-	0	12	8 *(4-13)*	15 *(8-26)*	10	-	-
Lower arm	0	0.0 -	0-	0	3	2 *(1-6)*	4 *(1-11)*	3	-	-
Wrist	1	1 *(0-5)*	1 *(0-9)*	1	5	3 *(1-7)*	6 *(3-15)*	4	0.2 *(0.0-1.7)*	0.103
Hand	1	1 *(0-5)*	1 *(0-9)*	1	7	4 *(2-9)*	8 *(4-18)*	6	0.1 *(0.0-1.2)*	0.034
Finger	0	0 -	0-	0	5	3 *(1-7)*	6 *(3-15)*	4	-	-
Chest	10	6 *(3-12)*	12 *(7-22)*	8	9	6 *(3-11)*	11 *(6-21)*	8	1.1 *(0.5-2.7)*	0.819
Back	2	1 *(0-5)*	2 *(1-10)*	2	1	1 *(0-4)*	1 *(0-9)*	1	2.0 *(0.2-22.0)*	0.564
Groin	17	11 *(7-17)*	21 *(13-33)*	13	4[a]	3 *(1-7)*	5 *(2-13)*	3	4.3 *(1.4-12.6)*	0.005
Hamstrings	2	1 *(0-5)*	2 *(1-10)*	2	1	1 *(0-4)*	1 *(0-9)*	1	2.0 *(0.2-22.0)*	0.564
Quadriceps	21	13 *(9-21)*	25 *(17-39)*	16	4[a]	3 *(1-7)*	5 *(2-13)*	3	5.3 *(1.8-15.2)*	<0.001
Knee	20	13 *(8-20)*	24 *(16-37)*	16	10	6 *(3-12)*	12 *(7-22)*	9	2.0 *(0.9-4.3)*	0.068
Lower leg	14	9 *(5-15)*	17 *(10-29)*	11	8	5 *(3-10)*	10 *(5-19)*	7	1.8 *(0.7-4.2)*	0.201
Ankle	10	6 *(3-12)*	12 *(7-22)*	8	5	3 *(1-8)*	6 *(3-15)*	4	2.0 *(0.7-5.8)*	0.197
Toe	1	1 *(0-5)*	1 *(0-9)*	1	0	0 -	0-	0	-	-
Injury region										
Head/Neck	21	13 *(9-21)*	25 *(17-39)*	16	18	11 *(7-18)*	22 *(14-34)*	15	1.2 *(0.6-2.2)*	0.631
Upper limb	14	9 *(5-15)*	17 *(10-29)*	11	57[a]	36 *(28-46)*	69 *(53-89)*	49	0.3 *(0.1-0.4)*	<0.001
Chest/Back	12	8 *(4-14)*	15 *(8-26)*	9	10	6 *(3-12)*	12 *(7-22)*	9	1.2 *(0.5-2.8)*	0.67
Lower limb	85	54 *(44-67)*	102 *(83-127)*	64	32[a]	20 *(14-28)*	39 *(27-55)*	27	2.7 *(1.8-3.9)*	<0.001
Injury type										
Bruise/Contusion	50	32 *(24-42)*	60 *(46-80)*	38	38	24 *(17-33)*	46 *(33-63)*	33	1.3 *(0.9-2.0)*	0.201
Strains	31	20 *(14-28)*	37 (26-53)	24	31	19 *(14-28)*	37 (26-53)	27	1.0 *(0.3-4.0)*	1
Sprains	27	17 *(12-25)*	33 (22-37)	21	22	14 *(9-21)*	27 *(18-40)*	19	1.2 *(0.7-2.1)*	0.475
Fracture/Dislocation	10	6 *(3-12)*	12 *(7-22)*	8	9	6 *(3-11)*	11 *(6-21)*	8	1.1 *(0.5-2.7)*	0.819
Concussion	10	6 *(3-12)*	12 *(7-22)*	8	7	4 *(2-9)*	8 *(4-18)*	6	1.4 *(0.6-3.7)*	0.467
Lacerations	3	2 *(1-6)*	4 *(1-11)*	2	4	3 *(1-7)*	5 *(2-13)*	3	0.8 *(0.2-3.3)*	0.706
Other	1	1 *(0-5)*	1 *(0-9)*	1	6[a]	4 *(2-9)*	7 (3-16)	5	0.1 *(0.0-1.5)*	0.034
Injury severity										
Transient (0 - 4 days)	100	64 *(52-78)*	121 *(99-147)*	76	101	63 *(52-77)*	122 *(100-148)*	86	1.0 *(0.8-1.3)*	0.944
Mild (4 - 7 days)	20	12 *(8-19)*	24 *(16-37)*	15	10	6 *(3-12)*	12 *(7-22)*	9	1.9 *(0.9-4.1)*	0.095
Moderate (7 - 21 days)	2	1 *(0-5)*	2 *(1-10)*	2	2	1 *(0-5)*	2 *(1-10)*	2	1.0 *(0.1-7.1)*	1
Major (21 days +)	10	7 *(4-13)*	12 *(7-22)*	8	4	3 *(1-7)*	5 *(2-13)*	3	2.8 *(0.9-8.6)*	0.071

Significant difference ($p \leq 0.05$) from (**a**)=ball carrier

Tackle-related injuries by match period, field location, player position and tackle number

The no. 8 prop recorded the highest number of total tackle-related injuries (485 per 1,000 match hours; 128 per 10,000 tackle events) and was also the most commonly injured ball carrier (266 per 1,000 match hours; 141 per 10,000 tackle events) (see Table 56). Forwards recorded significantly more injuries than backs (RR: 1.8 [1.2-2.6]; *p*=0.002) for all tackle-related injuries. This was similar for forwards, when compared with backs as the tackler (RR: 1.3 [1.1-1.7]; *p*=0.027) but not as the ball carrier (RR: 1.0 [0.7-1.4]; *p*=0.862).

Table 56: Player position and field position for tackle-related injury numbers, percentages and rates per 10,000 tackle events and rates per 1,000 match hours with 95% confidence intervals (95% CI) for ball carrier and tackler positions. Risk ratios are for comparisons of ball carrier versus tackler.

		Ball carrier injury rate per				Tackler injury rate per				Risk Ratio	
			10,000 tackle events	1,000 match hours			10,000 tackle events	1,000 match hours		ball carrier vs. tackler	
		No.	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**No.**	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**RR** *(95% CI)*	**p**
Player position											
	1. Fullback	13	108 *(63-185)*	204 *(118-351)*	10	5	41 *(17-98)*	78 *(32-188)*	4	2.6 *(0.9-7.3)*	0.059
	2. Right side Wing	7	58 *(28-122)*	110 *(52-230)*	5	1[a]	8 *(1-58)*	16 *(2-111)*	1	7.0 *(0.9-56.8)*	0.034
	3. Right side Centre	13	108 *(63-185)*	204 *(118-351)*	10	7	57 *(27-120)*	110 *(52-230)*	6	1.9 *(0.7-4.6)*	0.18
	4. Left side Centre	10	83 *(45-154)*	157 *(84-291)*	7	5	41 *(17-98)*	78 *(33-188)*	4	2.0 *(0.7-5.8)*	0.18
	5. Left side Wing	9	75 *(39-143)*	141 *(73-271)*	7	4	33 *(12-87)*	63 *(24-167)*	3	2.3 *(0.7-7.3)*	0.166
	6. Stand off	7	58 *(28-122)*	110 *(52-230)*	5	6	49 *(22-109)*	94 *(42-209)*	5	1.2 *(0.4-3.5*	0.782
	7. Half back	6	50 *(22-111)*	94 *(42-209)*	5	14	114 *(68-193)*	219 *(130-370)*	12	0.4 *(0.2-1.1)*	0.074
	8. Left side Prop	17	141 *(88-227)*	266 *(166-428)*	13	14	114 *(68-193)*	219 *(130-370)*	12	1.2 *(0.6-2.5)*	0.59
	9. Hooker	4	33 *(12-88)*	63 *(24-167)*	3	22[a]	179 *(118-272)*	345 *(227-523)*	19	0.2 *(0.1-0.5)*	<0.001
	10. Right side Prop	9	75 *(39-143)*	141 *(73-271)*	7	8	65 *(33-130)*	125 *(63-251)*	7	1.1 *(0.4-2.9)*	0.808
	11. Left side Second row	14	116 *(69-196)*	219 *(130-370)*	11	8	65 *(33-130)*	125 *(63-251)*	7	1.8 *(0.7-4.2)*	0.201
	12. Right side Second row	13	108 *(63-185)*	204 *(118-351)*	10	17	138 *(86-223)*	266 *(166-428)*	15	0.8 *(0.4-1.6)*	0.465
	13. Loose forward	10	83 *(45-154)*	157 *(84-291)*	8	6	49 *(22-109)*	94 *(42-209)*	5	1.7 *(0.6-4.6)*	0.317
	Forwards	67	256 *(202-325)*	484 *(381-615)*	51	75	282 *(225-353)*	542 *(432-680)*	64	1.1 *(0.8-1.5)*	0.502
	Backs	65	290 *(227-370)*	548 *(430-699)*	49	42[a]	184 *(136-249)*	354 *(262-479)*	36	0.6 *(0.4-0.9)*	0.026
Field position											
Defence	In goal	1	1 *(0-5)*	1 *(0-9)*	1	1	1 *(0-4)*	1 *(0-9)*	1	1.0 *(0.0-16.0)*	1
	0-10	4	3 *(1-7)*	5 *(2-13)*	3	10	6 *(3-12)*	12 *(7-22)*	9	0.4 *(0.1-1.3)*	0.109
	10-20	10	6 *(3-12)*	12 *(7-22)*	8	8	5 *(3-10)*	10 *(5-19)*	7	1.3 *(0.5-3.2)*	0.637
	20-30	22	14 *(9.2-21)*	27 *(18-40)*	17	7[a]	4 *(2-9)*	8 *(4-18)*	6	3.1 *(1.4-7.3)*	0.005
	30-40	20	13 *(8.2-20)*	24 *(16-37)*	15	12	8 *(4-13)*	15 *(8-26)*	10	1.7 *(0.8-3.4)*	0.157
	40-50	20	13 *(8.2-20)*	24 *(16-37)*	15	13	8 *(5-14)*	16 *(9-27)*	11	1.5 *(0.8-3.1)*	0.223
Attack	50-40	7	5 *(2-9)*	8 *(4-18)*	5	17[a]	11 *(7-17)*	21 *(13-33)*	15	0.4 *(0.2-1.0)*	0.041
	40-30	12	8 *(4-14)*	15 *(8-26)*	9	18	11 *(7-18)*	22 *(14-34)*	15	0.7 *(0.3-1.4)*	0.273
	30-20	13	8 *(5-14)*	16 *(9-27)*	10	9	6 *(3-11)*	11 *(6-21)*	8	1.4 *(0.6-3.4)*	0.394
	20-10	9	6 *(3-11)*	11 *(6-21)*	7	12	8 *(4-13)*	15 *(8-26)*	10	0.8 *(0.3-1.8)*	0.513
	10-0	13	8 *(5-14)*	16 *(9-27)*	10	8	5 *(3-10)*	10 *(5-19)*	7	1.6 *(0.7-3.9)*	0.275
	In goal	1	1 *(0-5)*	1 *(0-9)*	1	2	1 *(0-5)*	2 *(1-10)*	2	0.5 *(0.0-5.5)*	0.564

Significant difference ($p \le 0.05$) from (**a**)=ball carrier

There were significantly more tackle-related injuries in the second than in the first half of matches (RR: 1.5 [1.2-2.0]) (see Table 57). There were significantly more tackle-related injuries in the third

(RR: 1.6 [1.1-2.2]; *p*=0.013) and the fourth (RR: 1.5 [1.1-2.1]; *p*=0.024) match quarters when compared with the first and second match quarters. There were significantly less tackle-related injuries in the fifth, sixth and zero (RR: 29.0 [7.1-118.4] *p*=0.006) tackles when compared with the second tackle (see Table 57). There were significantly more tackle-related injuries recorded to the ball carrier than the tackler in the first (RR: 1.5 [1.0 – 2.2]; *p*=0.043) but not the second half of matches (RR: 1.1 [0.8-1.4]; *p*=0.684). Tackle related injuries varied by match quarter with the tackler recording significantly more tackle injuries in the third than any other quarter ($\chi 2$=14.5, df=3, *p*=0.002).

Table 57: Number of tackle and match period for tackle-related injury numbers, percentages and rates per 10,000 tackle events and rates per 1,000 match hours with 95% confidence intervals (95% CI) for ball carrier and tackler positions. Risk ratios are for comparisons of ball carrier versus tackler.

		Ball carrier injury rate per				**Tackler injury rate per**			**Risk Ratio**	
		10,000 tackle events	**1,000 match hours**			**10,000 tackle events**	**1,000 match hours**		**ball carrier vs. tackler**	
Tackle count	**No.**	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**No.**	**Rate** *(95% CI)*	**Rate** *(95% CI)*	**%**	**RR** *(95% CI)*	**p**
Tackle 0	2	1 *(0-5)*	2 *(1-10)*	2	0	0 -	0 -	0	-	-
Tackle 1	29	19 *(13-27)*	35 *(24-50)*	22	22	14 *(9-21)*	27 *(18-40)*	19	1.3 *(0.8-2.3)*	0.327
Tackle 2	31	20 *(14-28)*	37 *(26-53)*	24	27	17 *(12-25)*	333 *(22-47)*	23	1.1 *(0.7-1.9)*	0.599
Tackle 3	28	18 *(12-26)*	38 *(23-49)*	21	28	18 *(12-25)*	34 *(23-49)*	24	1.0 *(0.6-1.7)*	1
Tackle 4	22	14 *(9-21)*	27 *(18-40)*	17	24	15 *(10-22)*	29 *(19-43)*	21	0.9 *(0.5-1.6)*	0.768
Tackle 5	16	10 *(6-17)*	19 *(12-32)*	12	16	10 *(6-16)*	19 *(12-32)*	14	1.0 *(0.5-2.0)*	1
Tackle 6	2	1 *(0-5)*	2 *(1-10)*	2	0	0 -	0 -	0	-	-
Incomplete	2	1 *(0-5)*	2 *(1-10)*	2	0	0 -	0 -	0	-	-
Match period										
1st Quarter	33	21 *(15-30)*	159 *(113-224)*	25	16^{cd}	10 *(6-16)*	77 *(47-126)*	14	2.1 *(1.1-3.7)*	0.015
2nd Quarter	26	17 *(11-24)*	125 *(85-184)*	20	23^{cd}	14 *(10-22)*	111 *(74-167)*	20	1.1 *(0.7-2.0)*	0.668
3rd Quarter	35	22 *(16-31)*	169 *(121-235)*	27	42^{ab}	26 *(19-36)*	202 *(150-274)*	36	0.8 *(0.5-1.3)*	0.425
4th Quarter	38	24 *(18-33)*	183 *(133-252)*	29	36^{ab}	23 *(16-31)*	174 *(125-241)*	31	1.1 *(0.7-1.7)*	0.816

Significant difference (p≤0.05) from (**a**)=1st quarter; (**b**)=2nd quarter; (**c**)=3rd quarter; (**d**)=4th quarter.

Discussion

This is the first study to report the nature of rugby league tackles resulting in injury. The majority of injuries in the present study occurred in the tackle situation which is similar to previous studies for rugby league[78] and for rugby union.[30, 212] The rate of tackle-related injuries for both total (300 per 1,000 match hours; 79 per 10,000 tackle events) and missed match injuries (58 per 1,000 match hours; 15 per 10,000 tackle events) was similar to some (346 per 1,000 match hours[137] 243 per 1,000 match hours[58]); but not all (139 per 1,000 match hours;[223] 114 per 1,000 match hours;[230] 54 per 1,000 match hours (5 per 1,000 tackle events)[105] 12 per 10,000 tackle events[117]) published studies in professional rugby league. The differences between the published studies may be the use of different injury definitions as there is no universally accepted injury definition for rugby league.[29, 133, 155, 194] A recent report on injuries in the NRL identified that 36.4% of all reported injuries occurred while being tackled (as the ball carrier) while only 18.3% of all injuries occurred when executing a tackle (as the tackler) at the professional level of participation.[190] Their finding that 55% of injuries were tackle related is in conflict with our study findings of 94% of injuries recorded as a result of the tackle. The remaining injuries (exertion, twisting or collision with object or another person) accounted for 6% (21 per 1,000 match hours) of the total injuries recorded and were not included in this study. The current study percentage of tackle related injuries is nearly twice that of the 460 injuries reported for the entire NRL competition for 2008.[190] The competition included 16 teams which would equate to an average of 28.8 injuries per team. Yet this study reported 108 tackle injuries in the 2008 season which is nearly four times the average injuries recorded. As a result the team under study may have had the highest injury rate in the professional competition or there may have been under-reporting of the number of injuries that occurred in the NRL. The team under study did not make the final series in both years of the competition. Further longitudinal studies are warranted to evaluate the incidence of injuries in the NRL.

The most common tackle-related injuries occurred when the tackle involved contact with the ball carrier at shoulder height or mid torso region, in the blind vision area, and with two or more tacklers in total being involved which is similar to a recent study in rugby union.[66] This was similar for injuries to the tackler but more injuries occurred to the first than the second tackler when making contact with the ball carrier. It is not known whether the tackle-related injury occurred from contact with the ball carrier or whether the subsequent tackler involved in the tackle was part of the injury event. The direction and points of application of energy between the ball carrier and the tackler may account for the differences in the rate of injuries reported.[66, 212]

Previous studies on injuries at the professional level have reported that first half injuries are similar to Seward, et al.,[223] or slightly less than[185] second half match injuries. This is similar with the current study with less tackle-related injuries recorded in the first than the second half of matches for the ball carrier (45% vs. 55%), tackler (33% vs. 67%) and total (39% vs. 61%) tackle-related injuries.

Although studies on rugby league match injuries have reported these by match period, no study to date has reported tackle-related injuries by match period. Given there were more tackle-related injuries to the ball carrier than the tackler in the first half of matches, this may be reflective of the match intensity and the accumulative effects of multiple players involved in the tackle. However, the increased rate of tacklers being injured in the second half of matches may be reflective of the short-term accumulative effects of repetitive tackles, increased amounts of micro-trauma and the decreasing ability of the body to accommodate for the collisions required in tackle during the match. Other factors, such as fatigue, decrement of tackling technique and individual fitness may also account for the increases seen in the second half of matches.[77, 93]

More injuries were recorded on the second tackle alone, than in the whole set of six tackles. Despite this finding, the tackler recorded more injuries on the third tackle which may be characteristic of the style of play in rugby league. The style, type and frequency of tackles in rugby league have changed in line with changes in rules.[56] With the introduction of the 'dominant' tackle (when the ball carrier is moved backwards in the tackle and placed on their back at the completion of the tackle) and 'surrender' tackle (where the ball carrier attempts to dive to the ground) rules in the NRL in 2002, there was a noticeable increase in the number of players involved in the tackle. Defending teams endeavoured to keep the ball in the opposition's half to deny good field position for any attack. After teams had kicked for field position into the opposition's territory, more tacklers were involved in the tackle to slow down the play-the-ball and provide more time for the defensive line to set.[56] However, what has not been reported in this study or previously was whether the injured tackler was involved in the preceding tackle, nor how far from the preceding play the ball the tackle-related injury occurred. A possible explanation for the tackler's injuries may be an overload of the physical capabilities of the injured player due to the collision forces involved in repetitive tackling, especially in and around the area known as the "ruck" (immediately adjacent to where the play the ball occurs). Although players recorded an average of 20 ±10 tackles per match, the time between tackles was not recorded and was beyond the scope of this study. Future studies on rugby league injuries may consider these points for their injury analysis.

As with most,[78] but not all[121] studies in rugby league injuries, forwards recorded a higher tackling injury rate (tackler, ball carrier and total tackle-related injuries) than backs. Forwards had a 9% increased risk of injury in the tackle situation when compared to backs.[118] This was similar for the current study with forwards also having an increased risk of an injury compared with backs as the tackler (8%) and for total tackles (3%) but there was not an increased risk of injury as the ball carrier. These differences may reflect the style of match play of the particular team under study. In one study reporting on professional level participation,[117] backs were reported to have a higher injury rate than forwards as both ball carrier and tackler during rugby league matches. The current study had a higher injury rate for forwards than backs as the tackler but a similar injury rate as the ball carrier. Although previous research has shown that the ball carrier is the most likely person to receive an injury,[116] the increased injuries to the tackler may be reflective of the changes in the tackling style that have occurred since the previous study.

Transient injuries were included in this study as they accounted for over 80% of the total injuries recorded and have also been reported in other rugby league injury studies.[152, 153] Not all researchers report transient injuries,[194] despite transient injuries creating an impact on the financial resources of teams and the participation of players.[155, 161] To exclude transient injuries and just report tackle related injuries that resulted in missed matches would under-report the full impact that a collision sport such as rugby league has socioeconomically. Studies comparing time-loss and non-time-loss injuries have identified that non-time-loss injuries can account for up to 90% of the injuries recorded involving up to 65% of the treatment time required to treat and manage these injuries.[50, 205] No data were recorded to see if tackle related injuries (non-time-loss and time-loss) required more treatment sessions than non-tackle related injuries. Further research is warranted in this area to fully understand the impact of tackle related injuries in rugby league.

Not included in the current study are areas that may be able to further assist in the identification of risk factors for rugby league injuries. These are limitations to the current study and subsequent studies examining injuries in relationship to the tackle in rugby league should include the following areas for consideration: (1) The distance the tackler has travelled before the tackle has been attempted or completed; (2) The distance the ball-carrier has travelled before becoming involved in the tackle; (3) The number of tackles the tackler consecutively makes when involved in the tackle; (4) The number of tackles the ball-carrier is involved in while the attacking team has the ball; and (5) The velocity of the tackle for both the ball carrier and the tackler. Further studies are warranted to explore these aspects. Other limitations to this study are that only a single team's matches over two consecutive seasons were observed. The current team under study completed only 48 matches and did not enter into the finals series in both years of the competition. The injury rate may have differed as a result of this due to the increased match intensity that has been reported to occur at the finals series of the competition.[77, 87] The tackle related injury rate may not be a true reflection of the overall tackle related injury rate at this level of competition. The views of the tackles and the resulting injuries were from televised coverage of the matches from two views provided. Another limitation was none of the authors were directly involved in the matches or the injury assessment of the injured players. All injury data were provided retrospectively after the two seasons were completed. No other teams involved in the competition allowed access to their injury data to enable a broader comparison to be completed. Some players may have better peripheral vision than others so the effects of tackle direction may be less for some players.

No other studies reporting rugby league injuries have identified the field position or when in the tackle count injuries occurred. The finding that injury rates differed by field positions for the ball carrier and tackler may reflect the style of play employed by these teams in the competition. More injuries were recorded in the defensive half of the field, with the 50 to 40 metre zone being the most common area where tackle-related injuries occurred. Despite this finding, more tackle-related injuries were recorded by the ball carrier in their own half of the field, with the 20 to 30 metre zone the most common area recorded for a tackle-related injury to occur. This finding may reflect the opposition's efforts to keep the ball in the oppositions half through having more players involved in the tackle, as was shown with tacklers recording more injuries in their attacking (opposition's defensive) half of the field with the 40 to 30 metre zone the most common area recorded for an injury to occur.

Further studies into tackle-related rugby league injuries are warranted to gain an understanding of the types of injuries that can occur from different tackling situations. Also, studies exploring what movements should be focused on with technique training to help reduce the risk of injury are also warranted. The results of these studies can assist in tailoring injury prevention programs that aim to reduce the rate of tackle-related injuries and will assist in providing more information on rugby league injuries that occur as a result of the tackle.

Conclusion

The nature of tackle-related injuries for professional rugby league players varied for the ball carrier and the tackler. Tackle-related injuries occurred more to the ball carrier when tackled at shoulder or mid-torso height, in their blind vision, when involving two or more tacklers, and in the fourth quarter of matches. The tackler incurred more injuries as the first tackler involved in the tackle, when approaching the ball carrier's right peripheral vision field and in the third quarter of matches. Coaches should focus practicing correct technique (target zone between the thighs and under the arms, head to the side and driving with the legs) during tackling with two or more tacklers and when tackling in the ball carriers blind vision area.

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CHAPTER 11: THE EFFECT OF PLAYER POSITIONAL GROUPS ON THE NATURE OF TACKLES THAT RESULT IN TACKLE-RELATED INJURIES IN PROFESSIONAL RUGBY LEAGUE MATCHES

This chapter comprises the following paper submitted to *Journal of Sports Medicine and Physical Fitness.*

Reference

King, DA., Hume, & Clark, T. The effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches. *Submitted to Journal of Sports Medicine and Physical Fitness.*

Author contribution

King, D. 82%; Hume, P. 15%; Clark, T. 3%

Overview

To describe the effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches. Prospective observational epidemiology analyses for tackle-related injuries and video analyses for the nature of tackles were conducted for a single team in the National Rugby League (NRL) throughout the 2007 and 2008 competitions for a total of 48 games. Risk ratios (RR) were calculated for comparisons between positional groups (adjustable, hit-up forwards or outside backs). The total missed match tackle-related injury rate was 57.8 per 1000 player hours. Hit-up forwards recorded significantly more total tackle-related injuries than outside backs (RR: 1.3; $p=0.049$), but not more than adjustables (RR: 1.0; $p=0.922$). Hit-up forwards recorded significantly more chest-back tackle-related injuries than adjustables (RR: 6.0; $p=0.008$). Outside backs recorded significantly more tackle injuries as the ball carrier than the tackler (RR: 2.4; $p=0.015$) while adjustables recorded significantly more tackle injuries as the tackler than the ball carrier (RR: 1.8; $p<0.001$). Hit-up forwards had a higher incidence of contusions, and sprains while adjustables had a higher incidence of fracture/dislocations. There were no differences in injury severity between the positional groups. Player positional group had an effect on tackle-related injury type and injury site. Hit-up forwards and outside backs recorded more tackle-related injuries as a ball carrier than as a tackler, while in contrast, adjustables recorded more tackle-related injuries as the tackler than the ball carrier.

Introduction

Rugby league is an international collision sport played by junior, amateur, semi-professional and professional players.[72, 73, 76, 154] The game requires players to complete physically demanding activities such as running, tackling, passing and sprinting[77, 180] interspersed with short bouts of low intensity activity such as jogging and walking.[77, 180] Exposure to physical collisions and tackles is common in rugby league and musculoskeletal injuries occur as a consequence of participation in the sport.[27, 77, 114]

Playing success is dependent, at least in part, on the tackling ability of its participants to tolerate the physical collisions involved and to 'win' the tackling contest. Most studies reporting injuries in rugby league[78] have typically reported information relating to the incidence of injury, the injury site, type and the causes of the injury occurring. Although these studies have all contributed to the growing body of knowledge on rugby league injuries at all levels of participation, only a few studies[84, 101] have undertaken to report the injury incidence site, type and cause by player group but none have explored the most common activity that results in an injury - the tackle. Further analysis of tackle-related injuries by positional groups would enable a broader understanding of the injuries that occur from the tackle at all levels of participation in rugby league.

Aim

The aim of this study was to describe the effect of player positional groups on the nature of tackles that result in tackle-related injuries in professional rugby league matches.

Methods

A single professional rugby league team was followed for a total of 48 matches throughout 2007 and 2008. Matches were played at locations in Australia and in New Zealand. All matches were two halves of 40 minutes with an overall average match exposure of 830 playing hours for 13 on-field players (It is noted that there were 17 players in total counting bench substitutes so the average match exposure per player may be an overestimate).

Ethical consent

Ethical consent for the research was obtained from the AUT University Human Ethics Committee. Consent for access to individual player injury data was obtained from the participating professional rugby league club. Informed consent from the injured players was not obtained as they had a club contract that allowed analysis of their data. All recordings of matches were available through international television coverage.

Player positional groups' definitions

For the study we used the following definitions for player positional groups:[91]

- *Adjustables:* Players in the hooker, halfback, five-eighth or stand-off and loose forward positions. The main role of players in the adjustables groups is to direct the ball in attack, co-ordinating the defensive effort in the forwards and be the team's main play-makers.
- *Hit-up forwards:* Players in the second row (n=2) and prop (n=2) positions. The main role of players in the hit-up forwards groups is to run directly into the opposition's territory to break the defensive line, tackle the opposition and offload the ball to a supporting player to switch the point of attack or create a gap to run through.
- *Outside backs:* Players in the fullback, centre (n=2) and wing (n=2) positions. The main role of players in the outside backs groups is to chase down and tackle any player who breaks the first line of defence, to breach the defensive line on their respective sides on attack and as a support player to take an offload and keep the ball alive, or to provide an overlap or a different angle of attack in the centre of the field.

Injury data and definitions

A prospective observational cohort design was undertaken. All injuries that occurred in the team were assessed and recorded by the team medical staff (doctor, physiotherapist or rehabilitation coordinator). Injury date, player position,[78] time of injury, injury site and type,[77, 148] injury mechanism and injury severity (days unavailable for selection) were recorded.[77, 134] Definitions for injury data included:

a. *Missed match injuries:* A tackle that resulted in an injury that rendered the player unavailable for selection in the next match.
b. *Injury rate:* The number of injuries per 1000 match hours[155] where player match exposure was on average 830 hours.
c. *Injury mechanism:* The injury mechanisms of all 266 recorded injuries were reviewed by one auditor to identify whether they met the definition of a rugby league tackle (see later definitions). Of all injuries, 249 (94%) met the tackle-related injury mechanism criteria.
d. *Injury severity:* Classified as either transient (no matches missed), minor (one match missed), moderate (two to four matches missed), or major (five or more matches missed).[77, 134]

Video data and definitions of tackles and related characteristics

Video analyses of televised coverage of matches allowed documentation of the nature of rugby league tackles associated with tackle-related injuries. One analyst used *Sports Performer©* (Premier Concepts Pty Ltd, Sydney, Australia; http://www.sportsperformer.com.au) to code tackles noting the match date, venue, player number, number of tackle in the set, number of tacklers involved in the tackle, field location where the tackle occurred and whether the injured player was the ball carrier or the tackler. Slow time motion replay and *ImageJ* (http://rsb.info.nih.gov/ij/) were used to measure the degree of approach of the tackler to the ball carrier. Definitions for tackles and related characteristics included:

a. *Tackle:* A tackle occurs when the ball carrier is held by one or more of the opposing players and either the ball or hand of the arm holding the ball makes contact with the ground or the ball carriers cannot make any further progress. Section 11 of the International Laws of Rugby League[2] were used to define a tackle in regards to how the ball carrier was held by the tackler(s) to complete the tackle.
b. *Missed tackle:* Any unsuccessful attempt to complete a tackle where the tackler/defender has made contact with the ball carrier and they have broken from the tackle[2] before it is completed.
c. *Tackle number:* The team in possession of the ball is allowed five successive plays of the ball.[2] The ball is handed over to the opposition after the fifth play of the ball or when the team in possession (1) Is tackled a sixth time, commits an accidental breach (i.e. knock on, forward pass and possession changes team resulting in a 'zero tackle'), (2) Has a player held-up and unable to ground the ball in the opponents' in-goal, or (3) Kicks the ball directly into touch on the full.
d. *Tackle height:*[212] Classified according to five different regions of the body: (1) Lower legs – from the player's knees to their toes; (2) Hip and thigh – from above the player's knees to the player's hip level; (3) Mid-torso – from above the player's hip level to the level of the player's arm pit; (4) Shoulder – from the player's arm pit to the level of the shoulder including the arm; and (5) Head and neck – above the shoulder with any connection with the head and/or neck during the course of the tackle. When the injured player was the ball carrier, all tacklers involved in the tackle were recorded for tackle height. When the injured player was the tackler, only the injured player was recorded for tackle height.
e. *Tackle direction or orientation:*[106] Classified as: (1) Tackler being head-on to the ball carrier (0°); (2) Tackler being in the ball carrier's side vision (left side: 330°-359°; right side 001°-030°); (3) Tackler being in the ball carrier's peripheral vision (left side: 300°-329°; right side: 031°-060°) or in the ball carrier's blind vision (between 061°-299°) when the tackle occurred. When the injured player was the ball carrier all tacklers involved in the tackle were recorded for tackle direction or orientation relative to the ball carrier's view. When the injured player was the tackler, only the injured player was recorded for tackle direction or orientation.

f. *Field position:* Classified as either defence (the side in which the team must defend their own in-goal area in order to stop the opposition team scoring a try), or attack (the side in which the team must enter to score a try in the opposition in-goal area) halves of the field. A regulation field length is 100 metres with a maximum in-goal size of eight metres in depth. The field is divided into 10 metre sections marked from 0 (goal-line) to 50 (half-way) for both halves of the field.

Statistical analyses

Video data were cross-linked with injury data by one analyst using a Microsoft Excel spreadsheet by matching player name, date and time of play. Data were analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA) statistical software. Estimated injury rates per 1000 match hours based on average match exposure hours calculated as previously explained.[135, 136] Data were reported as means and standard deviations ±SD with 95% confidence intervals (CI) where appropriate.[240] To compare between injury rates, risk ratios (RR) were used. A one-sample chi-squared (χ^2) test was used to determine differences in the number of tackles made by the team under study compared with any of the opposition teams. Significant *p* values reported in the text are less than 0.001 if they are not specifically stated.

Results

Over the study period there were 266 total injuries reported (321 per 1000 match hours). The tackle accounted for 94% (n=249) of the total injuries recorded (300 per 1000 match hours). The ball carrier (159 per 1000 match hours) recorded more injuries than the tackler (141 per 1000 match hours; χ^2=0.9, df=1, p=0.342) but not significantly more.

Number of tackles

There was a total of 31655 tackles over the study period representing 589, ±50 (mean ±SD) completed tackles and 69, ±14 missed tackles per match. This comprised of tackles made by the team under study (n=15963; 298, ±31 completed and 34, ±10 missed tackles per match) and the opposition teams (n=15692; 291, ±37 completed and 34, ±13 missed tackle per match). There was no significant difference in the number of tackles made by the team under study when compared with the opposition teams (χ^2=2, df=1, p=0.128).

Table 58: Effect of player positional groups on injury rates per 1000 match hours with 95% confidence intervals by type, region and severity of tackle-related injury

	Adjustables			Hit-up Forwards			Outside Backs			Risk Ratio ADJ vs. HUF		Risk Ratio ADJ vs. OB		Risk Ratio HUF vs. OB	
Activity when injured	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**
Ball carrier	27[ab]	105.7 (72.5 to 154.2)	36.0	53[c]	207.6 (158.6 to 271.7)	53.0	52[c]	162.9 (124.1 to 213.8)	70.0	0.5 (0.3 to 0.8)	0.004	0.5 (0.3 to 0.8)	0.005	1.0 (0.7 to 1.5)	0.922
Tackler	48[b]	188.0 (141.7 to 249.4)	64.0	47[b]	184.1 (138.3 to 245.0)	47.0	22[ac]	68.9 (45.4 to 104.7)	30.0	1.0 (0.7 to 1.5)	0.918	2.2 (1.3 to 3.6)	0.002	2.1 (1.3 to 3.5)	0.003
Total	75	293.7 (234.2 to 368.3)	100	100[c]	391.6 (321.9 to 476.4)	100	74[a]	231.8 (184.6 to 291.2)	100	0.7 (0.6 to 1.0)	0.059	1.0 (0.7 to 1.4)	0.935	1.4 (1.0 to 1.8)	0.049
Injury type															
Contusions	26	101.8 (69.3 to 149.5)	34.7	37	144.9 (105.0 to 200.0)	37.0	24	75.2 (50.4 to 112.2)	33.0	0.7 (0.4 to 1.1)	0.166	1.1 (0.6 to 1.9)	0.777	1.5 (0.9 to 2.6)	0.096
Strains	15	58.7 (35.4 to 97.4)	20.0	19	74.4 (47.5 to 116.6)	19.0	17	53.3 (33.1 to 85.7)	23.0	0.8 (0.4 to 1.5)	0.493	0.9 (0.4 to 1.8)	0.724	1.1 (0.6 to 2.1)	0.739
Sprains	14	54.8 (32.5 to 92.6)	18.7	25	97.9 (66.2 to 144.9)	25.0	20	62.7 (40.4 to 97.1)	27.0	0.6 (0.3 to 1.1)	0.078	0.7 (0.4 to 1.4)	0.303	1.2 (0.7 to 2.2)	0.456
Fracture/Dislocations	10	39.2 (21.1 to 72.8)	13.3	6	23.5 (10.6 to 52.3)	6.0	3	9.4 (3.0 to 29.1)	4.1	1.7 (0.6 to 4.6)	0.317	3.3 (0.9 to 12.1)	0.052	2.0 (0.5 to 8.0)	0.317
Concussions	6	23.5 (10.6 to 52.3)	8.0	8	31.3 (15.7 to 62.6)	8.0	4	12.5 (4.7 to 33.4)	5.5	0.7 (0.3 to 2.2)	0.593	1.5 (0.4 to 5.3)	0.527	2.0 (0.6 to 6.6)	0.248
Other	4	15.7 (5.9 to 41.7)	5.3	5	19.6 (8.1 to 47.0)	5.0	5	15.7 (6.5 to 37.6)	6.8	0.8 (0.2 to 3.0)	0.739	0.8 (0.2 to 3.0)	0.739	1.0 (0.3 to 3.4)	1.000
Injury region															
Head/Neck	11	43.1 (23.9 to 77.8)	14.7	17	66.6 (41.4 to 107.1)	17.0	11	34.5 (19.1 to 62.2)	15.0	0.6 (0.3 to 1.4)	0.257	1.0 (0.4 to 2.3)	1.000	0.6 (0.3 to 1.4)	0.257
Upper Limb	30[b]	117.5 (82.1 to 168.0)	40.0	26	101.8 (69.3 to 149.5)	26.0	16[c]	50.1 (30.7 to 81.8)	22.0	1.2 (0.7 to 1.9)	0.593	1.9 (1.0 to 3.4)	0.039	1.6 (0.9 to 3.0)	0.123
Chest/Back	2[ab]	7.8 (2.0 to 31.3)	2.7	12[c]	47.0 (26.7 to 82.7)	12.0	8[c]	25.1 (12.5 to 50.1)	11.0	0.2 (0.0 to 0.7)	0.008	0.2 (0.1 to 1.2)	0.058	1.5 (0.6 to 3.6)	0.371
Lower Limb	32	125.3 (88.6 to 177.2)	42.7	45	176.2 (131.6 to 236.0)	45.0	39	122.2 (89.3 to 167.2)	53.0	0.7 (0.5 to 1.1)	0.138	0.8 (0.5 to 1.3)	0.406	1.2 (0.8 to 1.8)	0.513
Injury severity															
Transient	59	231.0 (179.0 to 298.2)	78.7	81	317.2 (255.1 to 394.4)	81.0	60	188.0 (145.9 to 242.1)	81.0	0.7 (0.5 to 1.0)	0.063	1.0 (0.7 to 1.4)	0.927	1.3 (1.0 to 1.9)	0.077
Mild	8	31.3 (15.7 to 62.6)	10.7	13	50.9 (29.6 to 87.7)	13.0	9	28.2 (14.7 to 54.2)	12.0	0.6 (0.3 to 1.5)	0.275	0.9 (0.3 to 2.3)	0.808	1.4 (0.6 to 3.4)	0.394
Moderate	2	7.8 (2.0 to 31.3)	2.7	2	7.8 (2.0 to 31.3)	2.0	0	0.0-	0.0	1.0 (0.1 to 7.1)	1.000	0.0	0.157	0.0	0.157
Major	6	23.5 (10.6 to 52.3)	8.0	4	15.7 (5.9 to 41.7)	4.0	4	12.5 (4.7 to 33.4)	5.4	1.5 (0.4 to 5.3)	0.527	1.5 (0.4 to 5.3)	0.527	1.0 (0.3 to 4.0)	1.000

RR: Risk ratio; CI: Confidence Interval;; Significant difference ($p \leq 0.05$) compared with: (**a**) Hit-up forwards (HUF); (**b**) Outside backs (OB); (**c**) Adjustables (ADJ).

Injury number, injury type, region and severity by player positional groups

Hit-up forwards recorded significantly more total tackle injuries than outside backs (RR: 1.3; 95% CI: 1.0 to 1.8; p=0.049) (see Table 58). Adjustables had significantly more injuries as the tackler than the ball carrier (RR: 2.2; 1.3 to 3.6; p=0.002) and outside backs had more injuries as the ball carrier than the tackler (RR: 1.9; 1.2 to 3.0; p=0.005). Although adjustables recorded more fracture-dislocations than outside backs (RR: 3.3; 0.9 to 12.1; p=0.052) and hit-up forwards (RR: 1.7; 0.6 to 4.6; p=0.317) there were no statistical differences observed. Hit-up forwards recorded significantly more chest-back tackle injuries than adjustables (RR: 6.0; 1.3 to 26.7; p=0.008). Adjustables recorded significantly more upper limb tackle injuries than outside backs (RR: 2.0; 1.1 to 3.7; p=0.025). There were no significant differences in injury severity for positional groups.

Injuries by match period and tackle number by player positional groups

There were significantly more tackle injuries over the match periods for adjustables (χ^2=10.3, df=3, p=0.016) but not for hit-up forwards (χ^2=3.2, df=3, p=0.362) or outside backs (χ^2=2.0, df=2, p=0.572) (see Table 59).

Injuries by player positional groups for ball carrier and tackler

Outside backs recorded significantly more tackle injuries as the ball carrier than the tackler (RR: 2.4; 1.4 to 3.9; p=0.015) while adjustables recorded significantly more tackle injuries as the tackler than the ball carrier (RR: 1.8; 1.1 to 2.8) (see Tables 60 and 61). There were significantly more lower-limb region tackle injuries for the ball carrier than the tackler for hit-up forwards (RR: 3.5; 1.7 to 7.0) and outside backs (RR: 4.6; 2.0 to 10.3) but not for adjustables (RR: 1.1; 0.6 to 2.3; p=0.724). There were significantly more missed match injuries for the ball carrier then the tackler for hit-up forwards (RR: 3.8; 1.2 to 11.3; p=0.012) and for outside backs (RR: 3.3; 0.9 to 12.1; p=0.052).

Table 59: Effect of player positional groups on injury rates per 1000 match hours with 95% confidence intervals by match period, tackle number

	Adjustables			Hit-up Forwards			Outside Backs			Risk Ratio ADJ vs. HUF		Risk Ratio ADJ vs. OB		Risk Ratio HUF vs. OB	
Match period	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**
1st Quarter	14	219.3 (129.9 to 370.3)	18.7	19	297.6 (189.8 to 466.6)	19.0	16	200.5 (122.8 to 327.3)	21.6	0.7 (0.4 to 1.5)	0.384	0.9 (0.4 to 1.8)	0.715	1.2 (0.6 to 2.3)	0.612
2nd Quarter	11[a]	172.3 (95.4 to 311.1)	14.7	23[c]	360.3 (239.4 to 542.2)	23.0	15	188.0 (113.3 to 311.8)	20.3	0.5 (0.2 to 1.0)	0.040	0.7 (0.3 to 1.6)	0.433	1.5 (0.8 to 2.9)	0.194
3rd Quarter	29	454.3 (315.7 to 653.7)	38.7	27	422.9 (290.0 to 616.7)	27.0	21	263.2 (171.6 to 403.6)	28.4	1.1 (0.6 to 1.8)	0.789	1.4 (0.8 to 2.4)	0.258	1.3 (0.7 to 2.3)	0.386
4th Quarter	21	328.9 (214.5 to 504.5)	28	31	485.6 (341.5 to 690.5)	31.0	22	275.7 (181.5 to 418.7)	29.7	0.7 (0.4 to 1.2)	0.166	1.0 (0.5 to 1.7)	0.879	1.4 (0.8 to 2.4)	0.216
Tackle number															
Tackle 0	0	0.0 -	0.0	0	0.0 -	0.0	2	6.3 (1.6 to 25.1)	2.7	0.0	1.000	0.0	0.157	0.0	0.157
Tackle 1	13	50.9 (29.6 to 87.7)	17.3	7[b]	27.4 (13.1 to 57.5)	14.9	19[a]	59.5 (38.0 to 93.3)	25.7	1.9 (0.7 to 4.6)	0.180	0.7 (0.3 to 1.4)	0.289	0.4 (0.2 to 0.9)	0.019
Tackle 2	21	82.2 (53.6 to 126.1)	28.0	12	47.0 (26.7 to 82.7)	25.5	16	50.1 (30.7 to 81.8)	21.6	1.7 (0.9 to 3.5)	0.117	1.3 (0.7 to 2.5)	0.411	0.7 (0.4 to 1.6)	0.450
Tackle 3	14	54.8 (32.5 to 92.6)	18.7	13	50.9 (29.6 to 87.7)	27.7	10	31.3 (16.9 to 58.2)	13.5	1.1 (0.5 to 2.3)	0.847	1.4 (0.6 to 3.1)	0.414	1.3 (0.6 to 2.9)	0.532
Tackle 4	11	43.1 (23.9 to 77.8)	14.7	10	39.2 (21.1 to 72.8)	21.3	16	50.1 (30.7 to 81.8)	21.6	1.1 (0.5 to 2.6)	0.827	0.7 (0.3 to 1.5)	0.336	0.6 (0.3 to 1.4)	0.239
Tackle 5	14[a]	54.8 (32.5 to 92.6)	18.7	5[c]	19.6 (8.1 to 47.0)	10.6	9	28.2 (14.7 to 54.2)	12.2	2.8 (1.0 to 7.7)	0.039	1.6 (0.7 to 3.6)	0.297	0.6 (0.2 to 1.7)	0.285
Tackle 6	1	3.9 (0.6 to 27.8)	1.3	0	0.0 -	0.0	1	3.1 (0.4 to 22.2)	1.35	0.0	0.317	1.0 (0.1 to 16.0)	1.000	0.0	0.317
Incomplete	1	3.9 (0.6 to 27.8)	1.3	0	0.0 -	0.0	1	3.1 (0.4 to 22.2)	1.35	0.0	0.317	1.0 (0.1 to 16.0)	1.000	0.0	0.317

RR: Risk ratio; CI: Confidence Interval; Significant difference ($p \leq 0.05$) compared with: (**a**) Hit-up forwards (HUF); (**b**) Outside backs (OB); (**c**) Adjustables (ADJ).

Table 60: Injury numbers, match time, injury type, injury region and injury severity by ball carrier for positional groups with 95% confidence intervals and percentage

		Adjustables Ball Carrier			Hit Up Forwards Ball Carrier			Outside Backs Ball Carrier		Risk Ratio ADJ vs. HUF		Risk Ratio ADJ vs. OB		Risk Ratio HUF vs. OB	
	No.	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**	**RR (95% CI)**	**p**
Injuries															
No of Injuries	27[bc]	105.7 (72.5 to 154.2)	36.0	53[a]	207.6 (158.6 to 271.7)	53.0	52[a]	162.9 (124.1 to 213.8)	70.3	2.0 (1.2 to 3.1)	0.004	1.9 (1.2 to 3.0)	0.005	1.0 (0.7 to 1.5)	0.922
Match time															
1st qtr	7	109.6 (52.3 to 230.0)	25.9	12	188.0 (106.7 to 331.0)	22.6	14	175.4 (103.9 to 296.2)	26.9	0.6 (0.2 to 1.5)	0.251	0.5 (0.2 to 1.2)	0.127	0.9 (0.4 to 1.8)	0.695
2nd qtr	3[b]	47.0 (15.2 to 145.7)	11.1	13[a]	203.6 (118.2 to 350.7)	24.5	10	125.3 (67.4 to 232.9)	19.2	4.3 (1.2 to 15.2)	0.012	3.3 (0.9 to 12.1)	0.052	1.3 (0.6 to 2.9)	0.532
3rd qtr	10	156.6 (84.3 to 291.1)	37.0	11	172.3 (95.4 to 311.1)	20.8	14	175.4 (103.9 to 296.2)	26.9	1.1 (0.5 to 2.6)	0.827	1.4 (0.6 to 3.1)	0.414	0.7 (0.3 to 1.6)	0.549
4th qtr	7[b]	109.6 (52.3 to 230.0)	25.9	17[a]	266.3 (165.5 to 428.4)	32.1	14	175.4 (103.9 to 296.2)	26.9	2.4 (1.0 to 5.8)	0.041	2.0 (0.8 to 4.9)	0.127	1.2 (0.6 to 2.4)	0.590
Injury type															
Sprains	3[bc]	11.7 (3.8 to 36.4)	1.2	12[a]	47.0 (26.7 to 82.7)	4.8	13[a]	40.7 (23.6 to 70.1)	5.2	4.0 (1.1 to 14.1)	0.020	4.3 (1.2 to 15.2)	0.012	1.1 (0.5 to 2.4)	0.841
Strains	7	27.4 (13.1 to 57.5)	2.8	12	47.0 (26.7 to 82.7)	4.8	10	31.3 (16.9 to 58.2)	4.0	1.7 (0.7 to 4.3)	0.251	1.4 (0.5 to 3.7)	0.467	1.2 (0.5 to 2.8)	0.670
Contusions	11	43.1 (23.9 to 77.8)	40.7	20	78.3 (50.5 to 121.4)	37.7	19	59.5 (38.0 to 93.3)	36.5	1.8 (0.9 to 3.8)	0.106	1.7 (0.8 to 3.6)	0.144	1.1 (0.6 to 2.0)	0.873
Fracture/Dislocations	4	15.7 (5.9 to 41.7)	14.8	3	11.7 (3.8 to 36.4)	5.7	3	9.4 (3.0 to 29.1)	5.8	1.3 (0.3 to 5.9)	0.705	1.3 (0.3 to 5.9)	0.705	1.0 (0.2 to 4.9)	1.000
Concussions	2	7.8 (2.0 to 31.3)	7.4	6	23.5 (10.6 to 52.3)	11.3	3	9.4 (3.0 to 29.1)	5.8	3.0 (0.6 to 14.8)	0.157	2.0 (0.5 to 8.0)	0.655	1.5 (0.3 to 9.0)	0.317
Other	0	0.0 -	0.0	0[c]	0.0 -	0.0	4[b]	12.5 (4.7 to 33.4)	7.7	0-	1.000	0 -	0.046	0 -	0.046
Injury region															
Head/Neck	4	15.7 (5.9 to 41.7)	14.8	9	35.2 (18.3 to 67.7)	17.0	8	25.1 (12.5 to 50.1)	15.4	2.3 (0.7 to 7.3)	0.166	2.0 (0.6 to 6.6)	0.248	1.1 (0.4 to 2.9)	0.808
Upper Limb	4	15.7 (5.9 to 41.7)	14.8	4	15.7 (5.9 to 41.7)	7.5	7	21.9 (10.5 to 46.0)	13.5	1.0 (0.3 to 4.0)	1.000	1.8 (0.5 to 6.0	0.366	1.8 (0.5 to 6.0	0.366
Chest/Back	2	7.8 (2.0 to 31.3)	7.4	5	19.6 (8.1 to 47.0)	9.4	5	15.7 (6.5 to 37.6)	9.6	2.5 (0.5 to 12.8)	0.257	2.5 (0.5 to 12.8)	0.257	1.0 (0.3 to 3.4)	1.000
Lower Limb	17[bc]	66.6 (41.4 to 107.1)	63.0	35[a]	137.1 (98.4 to 190.9)	66.0	32[c]	100.3 (70.9 to 141.8)	61.5	2.1 (1.2 to 3.6)	0.013	1.9 (1.1 to 3.4)	0.032	1.1 (0.7 to 1.7)	0.714
Injury Severity															
Transient	20[bc]	78.3 (50.5 to 121.4)	74.1	38[a]	148.8 (108.3 to 204.5)	71.7	42[a]	131.6 (97.2 to 178.0)	80.8	1.9 (1.1 to 3.2)	0.018	2.1 (1.2 to 3.5)	0.005	1.1 (0.7 to 1.7)	0.655
Mild	4	15.7 (5.9 to 41.7)	14.8	10	39.2 (21.1 to 72.8)	18.9	6	18.8 (8.4 to 41.8)	11.5	2.5 (0.8 to 7.9)	0.109	1.5 (0.4 to 5.3)	0.527	1.7 (0.6 to 4.6)	0.317
Moderate	0	0.0 -	0.0	2	7.8 (2.0 to 31.3)	3.8	0	0.0 -	0.0	0-	0.157	0-	1.000	0-	0.157
Major	3	11.7 (3.8 to 36.4)	11.1	3	11.7 (3.8 to 36.4)	5.7	4	12.5 (4.7 to 33.4)	7.7	1.0 (0.2 to 4.9)	1.000	1.3 (0.3 to 5.9)	0.705	1.3 (0.3 to 5.9)	0.705

Rate per 1000 player hours. % reported as percent of injuries for positional group as ball carrier. Significant difference (p≤0.05) between: (**a**) Adjustables (ADJ); (**b**) Hit up forwards (HUF); and (**c**) Outside backs (OB).

Table 61: Injury numbers, match time, injury type, injury region and injury severity by tackler for positional groups with 95% confidence intervals and percentage

	Adjustables Tackler			Hit Up Forwards Tackler			Outside Backs Tackler			Risk Ratio ADJ vs. HUF		Risk Ratio ADJ vs. OB		Risk Ratio HUF vs. OB	
	No.	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**No.**	**Rate (95% CI)**	**%**	**RR(95% CI)**	**p**	**RR(95% CI)**	**p**	**RR(95% CI)**	**p**
Injuries															
No of Injuries	48[c]	188.0 (141.7 to 249.4)	64.0	47[c]	184.1 (138.3 to 245.0)	47.0	22[ab]	68.9 (45.4 to 104.7)	29.7	1.0 (0.7 to 1.5)	0.918	2.2 (1.3 to 3.6)	0.002	2.1 (1.3 to 3.5)	0.003
Match time															
1st qtr	7	109.6 (52.3 to 230.0)	14.6	7	109.6 (52.3 to 230.0)	14.9	2	25.1 (6.3 to 100.2)	9.1	1.0 (0.4 to 2.8)	1.000	3.5 (0.7 to 16.8)	0.096	3.5 (0.7 to 16.8)	0.096
2nd qtr	8	125.3 (62.7 to 250.6)	16.7	10	156.6 (84.3 to 291.1)	21.3	5	62.7 (26.1 to 150.5)	22.7	1.3 (0.5 to 3.2)	0.637	1.6 (0.5 to 4.9)	0.405	2.0 (0.7 to 5.8)	0.197
3rd qtr	19[c]	297.6 (189.8 to 466.6)	39.6	16[c]	250.6 (153.5 to 409.1)	34.0	7[ab]	87.7 (41.8 to 184.0)	31.8	1.2 (0.6 to 3.2)	0.612	1.8 (1.0 to 3.1)	0.039	2.1 (1.2 to 3.8)	0.011
4th qtr	14	219.3 (129.9 to 370.3)	29.2	14	219.3 (129.9 to 370.3)	29.8	8	100.3 (50.1 to 200.5)	36.4	1.0 (0.5 to 2.1)	1.000	1.8 (0.7 to 4.1)	0.201	1.8 (0.7 to 4.1)	0.201
Injury type															
Sprains	11	43.1 (23.9 to 77.8)	4.4	7	27.4 (13.1 to 57.5)	2.8	4	12.5 (4.7 to 33.4)	1.6	1.6 (0.6 to 4.0)	0.346	2.8 (0.9 to 8.6)	0.071	1.8 (0.5 to 6.0)	0.366
Strains	8	31.3 (15.7 to 62.6)	3.2	13	50.9 (29.6 to 87.7)	5.2	10	31.3 (16.9 to 58.2)	4.0	1.6 (0.7 to 3.9)	0.275	1.3 (0.5 to 3.2)	0.637	1.3 (0.6 to 2.9)	0.532
Contusions	15[c]	58.7 (35.4 to 97.4)	31.3	17[c]	66.6 (41.4 to 107.1)	36.2	5[ab]	15.7 (6.5 to 37.6)	22.7	1.1 (0.6 to 2.3)	0.724	3.0 (1.1 to 8.2)	0.025	3.4 (1.3 to 9.2)	0.011
Fracture/Dislocations	6[c]	23.5 (10.6 to 52.3)	12.5	3[c]	11.7 (3.8 to 36.4)	6.4	0[ab]	0.0 -	0.0	2.0 (0.5 to 8.0)	0.317	0-	0.014	0-	0.083
Concussions	4	15.7 (5.9 to 41.7)	8.3	2	7.8 (2.0 to 31.3)	4.3	1	3.1 (0.4 to 22.2)	4.5	2.0 (0.4 to 10.9)	0.414	4.0 (0.4 to 35.7)	0.180	2.0 (0.2 to 22.0)	0.564
Other	4	15.7 (5.9 to 41.7)	8.3	5	19.6 (8.1 to 47.0)	10.6	2	6.3 (1.6 to 25.1)	9.1	1.3 (0.3 to 4.6)	0.739	2.0 (0.4 to 10.9)	0.414	2.5 (0.5 to 12.8)	0.257
Injury region															
Head/Neck	7	27.4 (13.1 to 57.5)	14.6	8	31.3 (15.7 to 62.6)	17.0	3	9.4 (3.0 to 29.1)	13.6	1.1 (0.4 to 3.1)	0.796	2.3 (0.9 to 9.0)	0.206	2.7 (0.7 to 1.0)	0.132
Upper Limb	26[c]	101.8 (69.3 to 149.5)	54.2	22[c]	86.2 (56.7 to 130.8)	46.8	9[ab]	28.2 (14.7 to 54.2)	40.9	1.2 (0.7 to 2.1)	0.564	2.9 (1.4 to 6.1)	0.004	2.4 (1.1 to 5.3)	0.020
Chest/Back	0[bc]	0.0 -	0.0	7[a]	27.4 (13.1 to 57.5)	14.9	3[a]	9.4 (3.0 to 29.1)	13.6	0-	0.008	0-	0.083	2.3 (0.6 to 9.0)	0.206
Lower Limb	15	58.7 (35.4 to 97.4)	31.3	10	39.2 (21.1 to 72.8)	21.3	7	21.9 (10.5 to 46.0)	31.8	1.5 (0.7 to 3.3)	0.317	2.1 (0.9 to 5.2)	0.088	1.4 (0.5 to 3.7)	0.467
Injury Severity															
Transient	39[c]	152.7 (111.6 to 209.0)	81.3	43[c]	168.4 (124.9 to 227.1)	91.5	18[ab]	56.4 (35.5 to 89.5)	81.8	1.1 (0.7 to 1.7)	0.659	2.2 (1.2 to 3.8)	0.005	2.4 (1.1 to 4.1)	0.001
Mild	4	15.7 (5.9 to 41.7)	8.3	3	11.7 (3.8 to 36.4)	6.4	3	9.4 (3.0 to 29.1)	13.6	1.3 (0.3 to 5.9)	0.705	1.3 (0.3 to 5.9)	0.705	1.0 (0.2 to 4.9)	1.000
Moderate	2	7.8 (2.0 to 31.3)	4.2	0	0.0 -	0.0	0	0.0 -	0.0	0-	0.157	0-	0.157	0-	1.000
Major	3	11.7 (3.8 to 36.4)	6.3	1	3.9 (0.6 to 27.8)	2.1	0	0.0 -	0.0	3.0 (0.3 to 28.8)	0.317	0-	0.830	0-	0.317

Rate per 1000 player hours. % reported as percent of injuries for positional group as tackler. Significant difference ($p \leq 0.05$) between: (**a**) Adjustables (ADJ); (**b**) Hit up forwards (HUF); and (**c**) Outside backs (OB).

Discussion

The current study described the effect of player positional groups on the nature of tackles that resulted in tackle-related injuries at the professional level of participation. Hit-up forwards had a higher injury rate than adjustables and outside backs which was similar to the findings of Gabbett.[84] Furthermore, in comparison to the other playing groups, hit-up forwards had a higher incidence of contusions, and sprains while adjustables had a higher incidence of fracture/dislocations. Hit-up forwards have been reported to be heavier, slower and have a greater skinfold thickness than adjustables and outside backs.[101] This higher skinfold thickness was suggested to have a protective effect against soft tissue type injuries although there is no published scientific evidence to support this claim.[101] Future studies exploring injuries by position groups should include physiological characteristics in their dataset to enable further assessment of protective factors such as skinfold thickness.

Tackling has been described as the most important skill in rugby league.[94] Playing success depends, at least in part, on the players tackling ability, the ability to tolerate physical collisions, and the ability to dominant in the tackle contest.[94] Players with a greater exposure to match environments have been reported to be older, more experienced, shorter and have a greater tackling technique.[94, 105] Additionally players with a greater tackling technique were more often found to be involved in a greater number of tackles per game than players that were younger, less experienced, taller and have a poorer tackling technique.[94, 105] As a result, it was suggested that those players with more match experience and a greater tackling technique were placed in positions where more tackling occurred where-as players with less match experience and a poorer tackling technique were selected into positions where tackling was minimal. The more experienced players were exposed to a higher number of tackles. A limitation to this study is that no physiological data were captured to identify player age and playing experience. Future studies exploring tackle injuries should include this type of data to enable comparisons to occur.

As shown in the current study, the incidence of injury for the ball carrier and the tackler varied by positional group, injury type and injury site. Adjustables recorded more fracture-dislocations as the tackler than ball carrier while hit-up forwards recorded more concussions as the ball carrier than as a tackler. These differences may be reflective of the match-play tactics employed by the team under study combined with the match-play tactics of the opposition team. Typically the ball is kicked down the field of play by the opposition to gain field position upon completing the set of attacking opportunities. By kicking the ball deep into the oppositions defence end of the field, the opposition must now undertake to regain the field possession in an attempt to score a try. The outside backs are primarily involved in retrieving opposition kicks and returning the ball back as far as possible.[160] As a result, they are more commonly involved in the first and second attacking moves while the rest of the team retires onside. This can be seen by the higher number of tackle-related injuries for outside backs at the zero and first tackles, as well as the higher injury incidence at the defence end of the field for the same positional group.

Previous research[77, 116, 230] has shown that the ball carrier records more injuries than the tackler in rugby league. Hit-up forwards and outside backs recorded more tackle-related injuries as the ball carrier than the tackler in our study while adjustables recorded more tackle-related injuries as the tackler than the ball carrier. This difference can be explained by the patterns of movement that the positional groups undertake in a match. Hit-up forwards generally play in the middle of the field. Their role is typically one of attacking or defending over short distances before they become involved in a tackle situation (approximately 5 m).[160] Adjustables play either side of the ruck typically outside the hit-up forwards and are often required to run a greater distance to be involved in the tackle situation (approximately 8-12 m) and to support other defenders in the tackle.[160] As a result of this role adjustables recorded more tackler than ball carrier injuries. Outside backs are typically positioned on the edges of the field and cover greater distances before becoming involved in a tackle situation than hit-up forwards and adjustables.[160] Outside backs are therefore required to carry the ball more often than adjustables and hit-up forwards reflecting the higher incidence of ball carrier tackle injuries than tackler injuries.

Conclusion

There was an effect of positional group on the nature of tackles that resulted in tackle-related injuries in professional rugby league matches. The characteristics of these groups and their roles in match play produced differences in the injury type and site.

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CHAPTER 12: PLAYER PERSPECTIVE ON RETURN TO PLAY FOLLOWING A MATCH OR TRAINING INJURY IN AMATEUR RUGBY LEAGUE

This chapter comprises the following paper submitted to N*ew Zealand Journal of Sports Medicine*.

Reference

King, DA., Hume, & Clark, T. Player perspectives on return to play after a match or training injury in amateur rugby league. *Submitted to New Zealand Journal of Sports Medicine.*

Author contribution

King, D. 82%; Hume, P. 15%; Clark, T. 3%

Overview

The aim of this study was to explore and document perspectives on the return to play of players that have missed a training and/or rugby league match as a direct result of an injury occurring from participation in rugby league activities. A prospective experimental study to identify, document and report player perspectives on reasons they returned to participation in rugby league as a result of incurring a missed match or missed training injury from rugby league activities was undertaken. A total of 63 people participated in the study having recorded a missed training and/or match injury from 178 training sessions and 85 matches. There were 20 training injuries (4 per 1000 training hours) and 73 match injuries (80 per 1000 match hours) that were recorded as resulting in missed training and/or match activities. The majority of injured players returning to play were in paid employment (73%) with 26% either unemployed or enrolled as a student and 1% self employed. Eighty percent of injured players saw a health professional as part of their rehabilitation process. The team coach was reported to have asked the player to return to rugby league activities in 28% of training return and 29% of match participation. More than three quarters of injured players felt that the recommended time off from training (75%) and match (80%) activities by health professionals were too long. The most powerful factor in their decision to return to play, according to a third of all players, was being told they could return to play by a health professional or coach. Of concern is that nearly a third also reported that the injury sustained was not as bad as first diagnosed. Therefore, it is crucial that players receive the best and perhaps more importantly the most qualified advice at the early stage of assessment to ensure correct treatment and ongoing management of their injuries**.**

Introduction

Played internationally,[87] rugby league is participated at junior,[92] amateur,[69] semi-professional[77] and professional[137] levels of participation. As rugby league is an intermittent collision sport there is a risk of musculoskeletal injury occurring from both the match and training environments due to the number of physical collisions and tackles that occur.[157] Injury may result in hospitalization, inability to participate in training and match activities and the inability to participate in work related activities. As a result of an injury occurring there may be loss of income to the injured player, financial costs for medical related care and job limitations owing to the severity and type of the injuries that have occurred.[157]

Players incurring any injury may find that they undergo physical and psychological challenges.[38, 201] These challenges can range from feelings of alienation and isolation from team mates, emotions of physical incapacitations and anxieties related to fear of re-injury and concerns about performance to pre-injury levels.[38, 201] Other challenges that the injured player may undergo are self identity, self worth, contending with physical limitations while undergoing the demands of rehabilitation.[38, 201] As a result of these challenges, injuries that occur from participation in sporting activities not only limit players' physical performances but may also place a stress on their psychological health and well being.

Alongside these challenges, the return to participation places yet another set of demands on the injured player. Demands such as selection back into the team, the capability to perform with their team mates and to retain a sense of affiliation with the coach, team and club may be motivating factors for deciding to either return to play or may be a source of self-doubt, worry and apprehension.[38, 201] Such demands may also influence the injured player to return before they are medically fit enough to fully participate risking further injury to the already injured area or an exacerbation of the injury necessitating longer rehabilitation or premature retirement from the sport.

The aim of this study was to explore and document: (1) Injuries that resulted in missed training and match participation as a consequence of participation in rugby league activities; and (2) Decisions for the return to participation of players that had missed a training and/or match rugby league activity as a direct result of an injury occurring from participation in rugby league activities.

Methods

The AUT Ethics Committee approved all experimental procedures for this study (AUTEC 08/44).

Data extraction

A prospective experimental study design was used to identify, document and report player perspectives on reasons they returned to participation in rugby league as a result of incurring an injury from rugby league activities that resulted in missing a match training session. A single recorder assessed all injuries using the injury definition[155] employed in other rugby league injury studies.

Participants

Amateur rugby league teams from a zonal region were studied from December 2008 through to October 2009 with competition games from March to August. All registered players were considered amateur as they derived their main source of income from other means and did not receive match payments. The 128 amateur rugby league registered players (93 and 73 in 2008 and 2009 respectively with 38 players competing in both seasons) had a mean ±SD age (yrs), height (m) and body mass (kgs) of 27.0 ±12.3 yrs, 1.79 ±0.05 m and 94.7 ±12.1 kgs respectively.

Injury exposure and injury data collection

The incidence, site, nature, and cause of playing injuries were prospectively studied. Injury data were collected from 178 training sessions and 85 matches, which included all trial, fixture, and finals matches. All matches were 80 minutes in duration while trainings varied from 90 minutes to 120 minutes with mean ±SD duration of 98 ±17 minutes per training session. This included the pre-season and competitive season period. Not all players attended every training session for various reasons. Training sessions were held three times a week in the pre-season period and then twice a week through the competitive phase of the domestic season. Training sessions were held twice a week through the competitive phase of the representative season.

Definition of injury

For the purpose of this study, an injury was defined as *"any injury that causes a player to be unable to participate in a rugby league training activity or to be selected in a competitive match"*.[155] Injuries were assessed during the match or training session, immediately after the injury event. Multiple injuries that resulted from the same activity were counted as one injury event. The head sports medic/trainer, a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment and management, recorded all injuries sustained during training and match activities using an injury reporting form.[153] Injuries were categorised according to the site, nature and cause of injury as previously described.[97, 156] The injuries were classified anatomically according to the site: head, eyes, nose, mouth, teeth, neck, shoulder arm, elbow, hand, finger, chest/trunk, back, groin, thigh, knee, lower leg, ankle and toe. Injuries were also described according to the nature of the injury: sprains, strains, bruises and contusions, haematomas, dislocations, lacerations, fractures, overuse, concussion and unspecified medical conditions.[97, 156]

Injuries were also classified according to the causative mechanism: tackling player, ball carrier, collision with player, collision with object, fall/stumble, slipped/tripped, scrum collapse, twisted, overexertion, temperature-related and other.[97, 156] Injuries were classified as either minor (1 missed training week), moderate (2-4 missed training weeks) or major (5 or more missed training weeks).[114]

Return to play questionnaire

A return to play questionnaire was specifically developed for this study. Several previously injured players were asked to provide possible questions for the identification of decisions influencing players return to sport. The return to play influences were explored using yes or no questions and a Likert scale ranging from no influence (0) to total influence (6) in their decision to return to participate in rugby league activities. A total of 14 questions were established for the Likert questionnaire. Demographic data (age, ethnicity, player position, activity frequency, occupational activity, work history), and injury history and medical clearance data were also included (see Figure 5).

Procedure

Following any injury occurring in the match or training activity, players were assessed by the head trainer. Players requiring further medical input were referred to the appropriate health care facility. Players with injuries identified as incurring a missed match or training activity were asked to participate in the study. Consent was sought and obtained for all enrolled players. When players elected to return to rugby league activities they were asked to complete the return to play questionnaire before commencing any activity. Players with injuries that may have resulted in lifelong consequences were required to obtain a written medical clearance before they could return to rugby league activities. Players with a recorded concussion were only allowed to return to rugby league activities after the required stand down period, were symptom free, had a medical clearance and were on a graduated return to play program[173, 174] as outlined in the New Zealand Rugby League concussion policy (http://www.nzrl.co.nz/files/nzrl_policies/nzrl_policy_concussion_april2008.pdf).

Statistical analyses

All data collected were entered into a Microsoft Excel spreadsheet and analysed using SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA). Injury rates were calculated as the number of injuries per 1000 training or match hours.[114, 135, 136] Data are reported as either means with 95% confidence intervals (CI) or standard deviations ±SD.[140, 240] A *t*-test was used to identify differences between categories in the questionnaire responses. The reliability or internal consistency of the questionnaire was assessed by estimating Cronbach's alpha (α) coefficient.[46, 140] An alpha coefficient for an internally consistent scale should be at least 0.70.[234] Significant p values reported in the text are less than 0.001 if they are not specifically stated. The level of significance was set at $p<0.05$.

INJURY RETURN QUESTIONNAIRE

All questions contained in this questionnaire are strictly confidential and will become part of the PhD study on rugby league injuries.

Name: ____________________ ID Code: ___ ___ ___ (Club Yr No.) [ ] M [ ] F **DOB:** ___ / ___ / ___ (DD MM YY)

Dominant hand: Left [ ] Right [ ] Player Position: ____________________

Ethnic Background:

[ ] NZ European/Pakeha	[ ] Tongan	[ ] South East Asian	[ ] Tokelauan
[ ] Other European	[ ] Niuean	[ ] Indian	[ ] Other (please specify)
[ ] NZ Maori	[ ] Fijian	[ ] Other Asian	____________________
[ ] Cook Island Maori	[ ] Other Pacific	[ ] Samoan	

PERSONAL WORK HISTORY

Occupation ____________________ ANZSCO Code No. [ ] [ ] [ ]

[ ] In paid employment (Part time or full time) [ ] I own/part own the company [ ] I am self employed [ ] I am not in paid employment [9] [1] [1]

Work Type [ ] Sedentary (Brief standing and walking) [ ] Light (Mainly standing and walking) [ ] Medium (Often lift 5 kg plus) [ ] Heavy (Often lift 9kg plus) [ ] Very heavy (Often lift 22kg plus)

In a typical work day, how may hours do you spend Sitting ______ hrs Standing ______ hrs Walking ______ hrs

How often during your working day do you:

	Not at all	Occasionally	Frequently	Continuously
Bend/Stoop	[ ]	[ ]	[ ]	[ ]
Squat	[ ]	[ ]	[ ]	[ ]
Crawl	[ ]	[ ]	[ ]	[ ]
Climb	[ ]	[ ]	[ ]	[ ]
Reach above shoulder level	[ ]	[ ]	[ ]	[ ]
Crouch	[ ]	[ ]	[ ]	[ ]
Kneel	[ ]	[ ]	[ ]	[ ]
Balancing	[ ]	[ ]	[ ]	[ ]
Pushing/Pulling	[ ]	[ ]	[ ]	[ ]

INJURY HISTORY

What body part was injured? ____________________ **Side:** Left [ ] Right [ ] Both [ ] N/A [ ]

What type of injury was it: ____________________

Did the injury occur in: **Training** Yes: [ ] No: [ ] **Match** Yes: [ ] No: [ ]

Did you see a health professional? Yes: [ ] No: [ ] If yes – was it a Dr [ ] Hospital [ ] Physiotherapist [ ] Other [ ] ____________

Did the injury result in you being off work? Yes: [ ] No: [ ] If yes for how long Days: _____ Weeks: _____

How long have you been off training? No: Trainings ________ No. Weeks ________

When was your last match? Date: ___/___/___ No. of matches ago [ ]

Did you rest as instructed? Yes: [ ] No: [ ] If no, why? ____________________

Did you get a clearance to return to: **Trainings?** Yes: [ ] No: [ ] **Matches?** Yes: [ ] No: [ ]

REASON FOR RETURNING TO TRAINING AND/OR MATCH PARTICIPATION

Training:	Returned as medically cleared to participate	Yes: [ ] No: [ ]	Coach asked me to return	Yes: [ ]	No: [ ]
	Felt the injury was better so returned anyway	Yes: [ ] No: [ ]	To be part of the team	Yes: [ ]	No: [ ]
	Players asked me to return	Yes: [ ] No: [ ]	Feel the time off was incorrect	Yes: [ ]	No: [ ]
	To keep my fitness up	Yes: [ ] No: [ ]			
Match	Returned as medically cleared to participate	Yes: [ ] No: [ ]	Coach asked me to return	Yes: [ ]	No: [ ]
	Felt the injury was better so returned anyway	Yes: [ ] No: [ ]	To be part of the team	Yes: [ ]	No: [ ]
	Players asked me to return	Yes: [ ] No: [ ]	Feel the time off was incorrect	Yes: [ ]	No: [ ]
	To keep my fitness up	Yes: [ ] No: [ ]			

Figure 6: Return to play demographic and injury questionnaire

Results

A total of 178 training sessions were completed over the study period with a training exposure of 10,162 training hours. There were 85 matches completed with a match exposure of 916 hours. A total of 63 players (49%) recorded a missed training or match activity injury over the 24 months of the study. Nearly a quarter of the people enrolled (22%) recorded more than one missed training or match injury with 4% recording two or more missed match injuries (see Table 62).

A total of 618 training hours (391 training days) and 267 match hours (201 matches) were recorded missed as a result of an injury from rugby league activities. The mean and standard deviation of training and match activities session loss over the study was 6.6 ±6.2 training hours (4.2 ±3.9 training days) and 2.9 ±2.6 match hours (2.2 ±2.0 matches) per player.

Injured player employment activities

The majority of injured players returning to play were in paid employment (73%) with 26% either unemployed or enrolled as a student and 1% self employed (see Table 63). Nearly a third of all players (32%) recorded their employment as often lifting 5 kgs plus (medium) while sedentary (28%), heavy (20%), light (15%) and very heavy (4%) were recorded less often. Players recorded an average 3.2 ±1.4 hrs standing, 2.5 ±1.6 hrs sitting and 2.3 ±1.3 hrs walking per day as part of their employment. As shown in Figure 5, 50% reported that they reach frequently during the day, 54% occasionally crouch and 4% bend or squat continuously.

Injured players health services utilization

Eighty percent of injured players saw an additional health professional (apart from the sports medic/trainer who was reviewing each of the injured players in the study) as part of their rehabilitation process (see Table 63). Nearly half (44%) of all injured players saw a physiotherapist, 34% of all injured players attended a hospital for their treatment and 10% saw their own medical practitioner.

Table 62: Missed training and match injuries by injury site, type, cause, severity and position per 1000 training player hours with 95% confidence intervals and percentage of injuries.

	2008						2009					
	Missed Match Injuries			Missed Training Injuries			Missed Match Injuries			Missed Training Injuries		
	No	Rate[1] (95% CI)	%	No	Rate[2] (95% CI)CLR	%	No	Rate[1] (95% CI)CLR	%	No	Rate[2] (95% CI)CLR	%
Total	47	104.6 (78.6 to 139.2)	100.0	23	4.2 (2.8 to 6.3)	100.0	44	94.3 (70.1 to 126.7)	100.0	20	4.3 (2.8 to 6.7)	100.0
Injury Site												
Head/Neck	14[d]	31.1 (18.4 to 52.6)	29.8	1[bc]	0.2 (0.0 to 1.3)	4.3	8[b]	17.1 (8.6 to 34.3)	18.2	1[c]	0.2 (0.0 to 1.5)	5.0
Upper Limb	17[d]	37.8 (23.5 to 60.8)	36.2	9[a]	1.6 (0.8 to 3.1)	39.1	19[ad]	40.7 (26.0 to 63.8)	43.2	1[c]	0.2 (0.0 to 1.5)	5.0
Lower Limb	13[d]	28.9 (16.8 to 49.8)	27.7	10[a]	1.8 (1.0 to 3.4)	43.5	11	23.6 (13.0 to 42.5)	25.0	18[abd]	3.9 (2.4 to 6.2)	90.0
Chest/Back	3[abc]	6.7 (2.2 to 20.7)	6.4	3	0.5 (0.2 to 1.7)	13.0	6[b]	12.9 (5.8 to 28.6)	13.6	0[c]	0.0 -	0.0
Injury Type												
Sprain	4[hi]	8.9 (3.3 to 23.7)	8.5	3	0.5 (0.2 to 1.7)	13.0	4[fh]	8.6 (3.2 to 22.8)	9.1	1[f]	0.2 (0.0 to 1.5)	5.0
Strain	7	15.6 (7.4 to 32.7)	14.9	10[g]	1.8 (1.0 to 3.4)	43.5	16[egh]	34.3 (21.0 to 55.9)	36.4	16[eghi]	3.5 (2.1 to 5.6)	80.0
Concussion	8	17.8 (8.9 to 35.6)	17.0	0[fh]	0.0 -	0.0	5[fh]	10.7 (4.5 to 25.7)	11.4	1[f]	0.2 (0.0 to 1.5)	5.0
Fracture/Dislocation	14[e]	31.1 (18.4 to 52.6)	29.8	7[g]	1.3 (0.6 to 2.7)	30.4	19[ei]	40.7 (26.0 to 63.8)	43.2	2[f]	0.4 (0.1 to 1.7)	10.0
Other	14[e]	31.1 (18.4 to 52.6)	29.8	3	0.5 (0.2 to 1.7)	13.0	6[fgh]	12.9 (5.8 to 28.6)	13.6	0[f]	0.0 -	0.0
Injury Cause												
Tackled	28[lm]	62.3 (43.0 to 63.6)	38.3	5	0.9 (0.4 to 2.2)	21.7	21[lm]	45.0 (29.3 to 69.0)	47.7	1[m]	0.2 (0.0 to 1.5)	5.0
Tackling	18[lm]	62.3 (25.2 to 90.2)	59.6	5	0.9 (0.4 to 2.2)	21.7	17[lm]	36.4 (22.6 to 58.6)	38.6	1[m]	0.2 (0.0 to 1.5)	5.0
Collision	0[jk]	0.0 -	0.0	2[m]	0.4 (0.1 to 1.4)	8.7	1[jk]	2.1 (0.3 to 15.2)	2.3	1[m]	0.2 (0.0 to 1.5)	5.0
Other	1[jk]	2.2 (0.3 to 15.8)	2.1	11[l]	2.0 (1.1 to 3.6)	47.8	5[jk]	10.7 (4.5 to 25.7)	11.4	17[jkl]	3.7 (2.3 to 5.9)	85.0
Injury Severity												
Mild	23[o]	51.2 (34.0 to 77.0)	48.9	14[op]	2.5 (1.5 to 4.3)	60.9	22	47.1 (31.0 to 71.6)	50.0	16[op]	3.5 (2.1 to 5.6)	80.0
Moderate	8[n]	17.8 (8.9 to 35.6)	17.0	4[n]	0.7 (0.3 to 1.9)	17.4	11	23.6 (13.0 to 42.5)	25.0	2[n]	0.4 (0.1 to 1.7)	10.0
Major	16	35.6 (21.8 to 58.1)	34.0	5[n]	0.9 (0.4 to 2.2)	21.7	11	23.6 (13.0 to 42.5)	25.0	2[n]	0.4 (0.1 to 1.7)	10.0
Injury by Position												
Forwards	26	125.3 (85.3 to 184.0)	55.3	13	2.4 (1.4 to 4.1)	56.5	24	111.4 (74.7 to 166.2)	54.5	10	2.2 (1.2 to 4.0)	50.0
Backs	21	86.8 (56.6 to 133.1)	44.7	10	1.8 (1.0 to 3.4)	43.5	20	79.6 (51.3 to 123.3)	45.5	10	2.2 (1.2 to 4.0)	50.0

Rate expressed per (**1**) 1000 player hours; (**2**) 1000 training hours. CI: Confidence Interval. Significant difference (p<0.05) than (**a**)=Head/Neck; (**b**)=Upper Limb; (**c**)=Lower Limb; (**d**)=Chest/Back; (**e**)=Sprain; (**f**)=Strain; (**g**)=Concussion; (**h**)=Fracture / Dislocation; (**i**)=Other; (**j**)=Tackled; (**k**)=Tackling; (**l**)=Collision; (**m**)=Other; (**n**)=Mild; (**o**)=Moderate; (**p**)=Major.

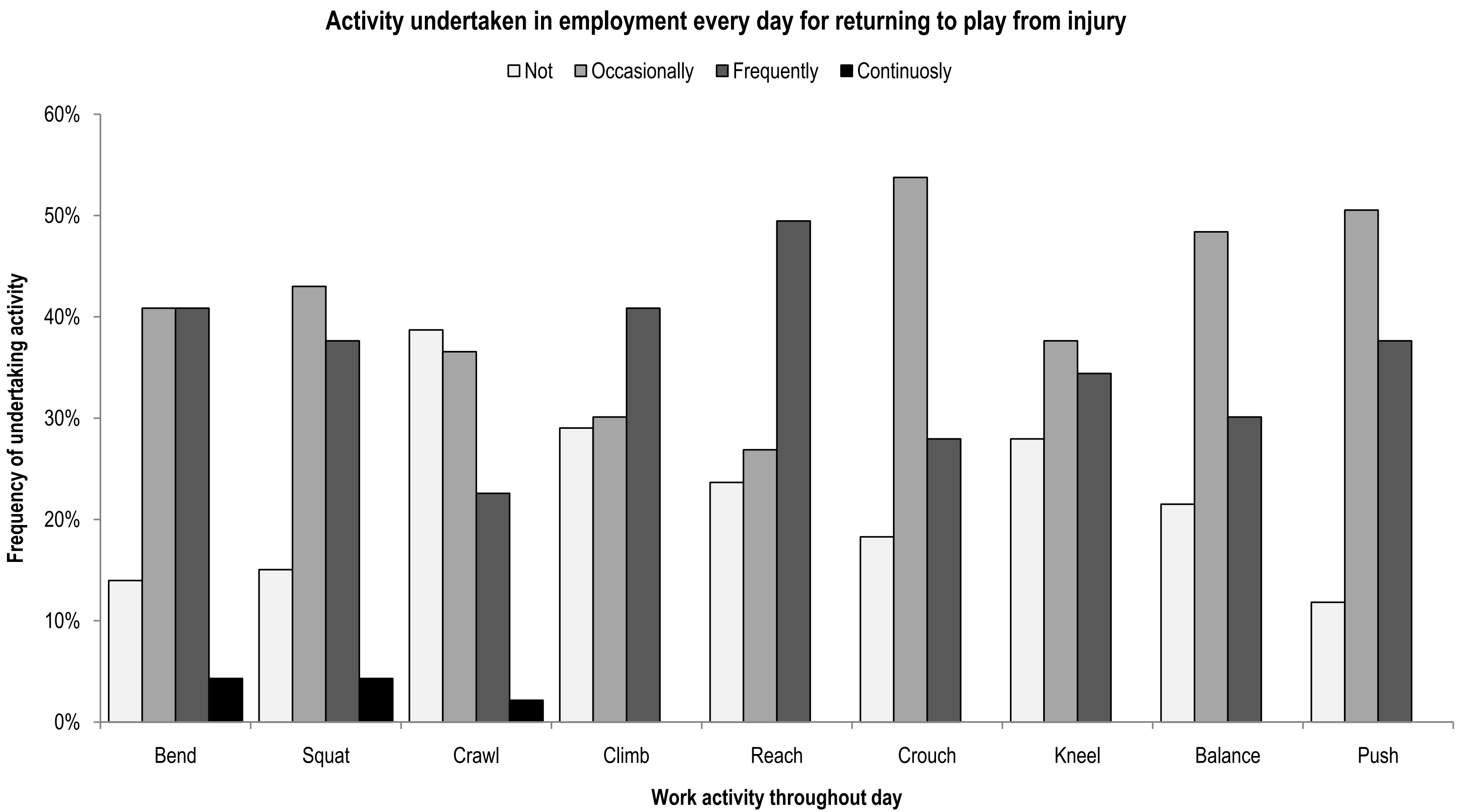

Figure 7: Reported percentages of activity undertaken during course of employment of players returning from injury from rugby league activities.

Table 63: Percentage (number) of participant's employment status, work type and utilisation of health professionals for players with a missed training/match injury

	% (n=)
Employment status	
Paid employed	73.1 (68)
Self employed	1.1 (1)
Not employed	25.8 (24)
Work Type	**% (n=)**
Sedentary (Brief standing or walking)	28.0 (26)
Light (Mainly standing or walking)	15.1 (14)
Medium (often 5 kgs plus)	32.3 (30)
Heavy (often lift 9 kgs plus)	20.4 (19)
Very heavy (often lift 22 kgs plus)	4.3 (4)
Utilisation of health professionals	**% (n=)**
Seen health professional	79.6 (74)
Seen own doctor	9.7 (9)
Seen at hospital	34.4 (32)
Seen physiotherapist	44.1 (41)
Seen other health professional	0.0 (0)
Rest as part of rehabilitation	**% (n=)**
Rested while rehabilitating	37.6 (35)

Percentage of total participants.

Table 64: Percentage (number) of "No" responses for reasons why players returned to rugby league match and training activities.

	Match Activities % (n=)	**Training Activities % (n=)**
Returned as medically cleared to participate	69.9 (65)[a]	80.6 (75)[a]
Coach asked me to return	72.0 (67)[a]	71.0 (66)[a]
Felt the injury was better so returned anyway	2.2 (2)[a]	3.2 (3)[a]
To be part of the team	2.2 (2)[a]	2.2 (2)[a]
Players asked me to return	63.4 (59)[a]	63.4 (59)[a]
Feel the time off was incorrect	24.7 (23)[a]	20.4 (19)[a]
To keep my fitness up	15.1 (14)[a]	18.3 (17)[a]

Rate in percentage of responses. Significant difference ($p<0.05$) for (**a**)=compared with yes responses.

Return to play questionnaire

The Cronbach's α for the questionnaire was 0.78. This means that the questionnaire had an acceptable to good internal reliability.[108] Only a third of all injured players (38%) reported they had rested as part of their rehabilitation from the injury they had incurred (see Table 64). Only 31% (37% training; 26% match) of injured players obtained a medical clearance to return to match and training activities. A quarter of injured players (29%) identified the team coach had asked them to return to any rugby league activities. This was similar for injured players returning to training (28%) and match (29%) related activities. There were significantly more "moderate" influences than "not at all" (t=-1.71, df=26, p=0.049), "slight" (t=-4.06, df=26), "strong" (t=2.12, df=26, p=0.019) "very strong" (t=2.57, df=26, p=0.008) and "total" (t=4.43, df=26) influences reported over the duration of the study (see Table 65). Nearly half (43%) of injured players reported that their contribution to the team being valued was a moderate influence on their return to play or training related activities. The player's contribution to the team (moderate; 50%) and players wanting to retain their playing position on the team (moderate; 29%) were also important factors affecting their decision to return to play.

A third of all participants (33%) reported that being told they could "return to participation" had some influence on their decision to recommence team activities. Half of the participants (56%) reported that being asked to return to team activities by a member of the team management had some influence on their decision to return with 22% identifying that this was a mild influence. Most, but not all injured participants felt that the injury was better for either the next training (98%) or match (97%) participation. Nearly a third of participants (30%) reported that they felt strongly that the injury was not as bad as they were told it was with slightly less (25%) reporting this was a strong influence in their decision to return to team activities. Three quarters of injured players felt that the recommended times off from training (75%) or match (80%) activities were too long.

Table 65: Results of questionnaire for players with a missed match and/or training injury by percentages (number of responses) for return to training / match activities influences.

	Question	Response							Mean ±*SD*
		Not at all[d] **% (n=)**	**Slight**[cde] **% (n=)**	**Mild**[bg] **% (n=)**	**Moderate**[abefg] **% (n=)**	**Strong**[bdg] **% (n=)**	**Very Strong**[d] **% (n=)**	**Totally**[cdef] **% (n=)**	
1	I felt I was needed by the team	0.0 (0)	4.3 (4)	17.2 (16)	**54.8 (51)**	19.4 (18)	2.2 (2)	2.2 (2)	3.0 ±0.9
2	I felt that the injury was not as bad as I was told it was	5.4 (5)	7.5 (7)	23.7 (22)	9.7 (9)	**26.9 (25)**	24.7 (23)	2.2 (2)	3.3 ±1.6
3	I felt that there was not an injury to worry about	9.7 (9)	6.5 (6)	**28.0 (26)**	19.4 (18)	12.9 (12)	21.5 (20)	2.2 (2)	2.9 ±1.6
4	The Coach/Manager/Trainer asked me to return	**49.5 (46)**	23.7 (22)	21.5 (20)	5.4 (5)	0.0 (0)	0.0 (0)	0.0 (0)	0.8 ±1.0
5	I feel my contribution to the team is valuable	2.2 (2)	2.2 (2)	40.9 (38)	**43.0 (40)**	5.4 (5)	2.2 (2)	4.3 (4)	2.7 ±1.1
6	I feel that my contribution to the team is valued by the coach	2.2 (2)	4.3 (4)	**61.3 (57)**	19.4 (18)	9.7 (9)	3.2 (3)	0.0 (0)	2.4 ±0.9
7	I feel that my contribution to the team is valued by the players	0.0 (0)	10.8 (10)	9.7 (9)	**49.5 (46)**	28.0 (26)	2.2 (2)	0.0 (0)	3.0 ±0.9
8	The upcoming game is important for the club/team and I want to be part of it	2.2 (2)	4.3 (4)	10.8 (10)	**32.3 (30)**	11.8 (11)	29.0 (27)	9.7 (9)	3.7 ±1.5
9	I don’t like watching the game and would rather be playing	0.0 (0)	0.0 (0)	5.4 (5)	12.9 (12)	**28.0 (26)**	26.9 (25)	26.9 (25)	4.6 ±1.2
10	know my body and it is alright to come back and play	0.0 (0)	7.5 (7)	12.9 (12)	19.4 (18)	14.0 (13)	**32.3 (30)**	14.0 (13)	3.9 ±1.5
11	I can play and see the physiotherapist if I get injured again	10.8 (10)	1.1 (1)	12.9 (12)	**45.2 (42)**	20.4 (19)	4.3 (4)	5.4 (5)	3.0 ±1.4
12	I want my spot back on the team and will do anything to make sure I play	3.2 (3)	5.4 (5)	28.0 (26)	**29.0 (27)**	17.2 (16)	15.1 (14)	2.2 (2)	3.1 ±1.3
13	I was told that I can play as the injury won’t get any worse	**66.7 (62)**	20.4 (19)	4.3 (4)	4.3 (4)	0.0 (0)	2.2 (2)	2.2 (2)	0.7 ±1.3
14	I can play as long as I am strapped on my injured area	26.9 (25)	3.2 (3)	4.3 (4)	**29.0 (27)**	22.6 (21)	11.8 (11)	2.2 (2)	2.6 ±1.8

Percentages are of total responses. Significant difference ($p<0.05$) than (**a**)=Not at all; (**b**)=Slight; (**c**)=Mild; (**d**)=Moderate; (**e**)=Strong; (**f**)=Very Strong; (**g**)=Totally. Bold indicates the highest percentage for a question.

Discussion

The incidence of injury in rugby league has been well documented.[78, 159] There are numerous occasions where as the result of injury sustained whilst playing and training for rugby league activity players have had to miss crucial games in their careers. This is the first study to identify, document and report player perspectives on reasons why they returned to match and training activities following a missed match/training injury. The reported injury rate for matches (402 per 1000 player hours) was higher than some,[69] but not all[152] studies for amateur participation. This was similar for the training injury rate (9 per 1000 training hours) reported with the current rate less than other studies[151] for amateur participation.

A third of all the injured players rested as part of their rehabilitation process (i.e., they missed at least one training session or match as a result of the injury, and missed work). This low number of resting players may be reflective of the participation status of the players. Amateur players receive no financial compensation for participating in rugby league and therefore must derive their income from other employment. With a quarter of players reporting their employment requiring lifting heavy or very heavy objects the opportunity to rest is reduced. Additionally the mean standing and walking per day recorded was in excess of five hours which may further compromise any lower limb rehabilitation requirements. Not recorded in this study is whether those players with a reoccurring injury actually rested with this injury when compared with the initial injury or whether they were required to continue to work in their employment in either a standing or walking situation. These data would be beneficial in future studies researching amateur player return to play decisions and influences.

Although nearly half of the participants reported seeing a physiotherapist as part of their rehabilitation, this may change in the current political environment of New Zealand. Throughout the duration of the study the Accident Compensation Corporation (ACC) provided fully subsided medical care through services such as a physiotherapist. Since completing the study there has been a change in government, resulting in legislative changes to the Injury Prevention, Rehabilitation, and Compensation Act (2001). A result of this change has seen the reintroduction of surcharges for visits to physiotherapists. The implications of these changes may see a downward trend in attendance to physiotherapists or other health care providers as the majority of participants are ‘blue collar’ class of occupations in the employment sector.[158] Financial restrictions may influence the use of the physiotherapist for rehabilitation from the injury that has occurred. This could result in an upward trend in the incidence of missed match injuries or reoccurrence of the same injury as a result of incomplete rehabilitation. Further studies are warranted to identify if the legislative changes result in an increase in the incidence of injuries due to decreased use of rehabilitation services.

Medical clearance for return to sports participation was reported to have occurred in less than a third of injured players for match situations and less than a quarter of injured players for training situations. As well, more than three quarters of players returning from injury identified that they felt the time off for the injury rehabilitation was too long. For example, players who had recorded a concussion from match or training activities reported they felt alright to return to full training and/or match activities before the New Zealand Rugby League stipulated guideline of three weeks. Regardless of this, all players with an assessment of concussion were required to undergo a return to play protocol, be symptom free, have three weeks stand down and be medically cleared before they could return to full contact training or match activities. Players who have incurred an injury resulting in a missed match or training activity should, ideally, be managed in their rehabilitation process with the assistance of other health professionals. Clearance to return to rugby league activities should, ideally, be with the cooperation of the team management and the health professional ensuring that the returning player is best managed to ensure that no exacerbation of the injury occurs.

Communication between the team management and the health service involved in the injured players rehabilitation is another reported influence for players returning to sport.[203] As the team trainer involved in this research was a registered nurse with tertiary qualifications in sports medicine, there was communication established with some rehabilitation services' enabling the coach to receive direct feedback in regards to individual player injury rehabilitation on some of the players seen at the rehabilitation services. This may be seen as a bias in this study as not all teams have qualified team trainers with this level of professional qualifications and established networks. Also, coaches of the teams involved in this study were retired professional players and had been exposed to a high level of medical services as part of their professional career. Local coaches with a family member supporting them in the role of the trainer or team manager may not be aware of the influences they may impart on players returning from an injury. Further research is warranted on amateur coaches in these areas and this information could be incorporated into injury prevention modules for coach education.

Nearly a third of players reported they were asked by the coach to return to match and/or training activities. The coaches' decision to ask a player to return to play may have been influenced by several interlinked coaching philosophies: (1) The player's status in the team (i.e. reserve player, starting player), match situation (i.e. a close game, win/loss situation) and the importance of the competition;[203] (2) Some coaches may want nothing to do with athletes with injuries, or around the team environment as this may have a potential "contaminating effect" on other team members;[203] (3) The role the coach undertakes (i.e. parental figure assisting with athletes or primary role to ensure physical readiness to perform);[203] and (4) Awareness of potential psychological stressors involved in returning to sport after injury and whether the coach feels comfortable dealing with these.[203]

Injured players returning to match and training activities indicated that team involvement was important to them. In particular areas of motivation reported in this study were the desire to retain their spot in the team, they did not like watching from the sideline, the game was important to them and they felt they were needed by the team. Team affiliation and sense of belonging have been reported to be key motivators for players wanting to return from injury.[201] The findings of this study are similar to another study[202] where team sports participants reported that they wanted to regain a spot in the team and to "have an impact" on teams performance. They reported a love of the sport, wanting to keep fitness up, bonding and socializing with team mates and to retain their athletic identity as key motivators to return to sport.[202] These themes were similar to the themes in the current study where players reported that team related factors influenced their decisions for returning to sport.

Not reported in this study, but an important consideration for future studies is whether there was any re-injury anxiety for players returning to match and training participation. Players returning to competition activities have been reported to undergo re-injury anxiety and whether they are going to be able to perform to their own pre-injury level of participation.[201, 204, 245] Not reported in other studies on return from injury to sports is what impact being an amateur participant has on these returning anxiety states. As previously identified, amateur participants rely on other employment to secure a financial income and becoming injured again may risk their employment, impact on their financial status or place further financial burden on their income. These areas are of concern for the amateur participant and warrant further exploration.

Conclusion

This study has reported the lacuna of information in regards to the player perspectives on why they returned to rugby league match and training activities. Of concern is that nearly a third of players reported that the injury sustained was not as bad as first diagnosed. Therefore, it is crucial that players receive the best and perhaps more importantly the most qualified advice at the early stage of assessment to ensure correct treatment and ongoing management of their injuries. The finding that only 31% of injured players reported having a medical clearance, and a third of injured players reported they were asked by team management to return to training and match activities before they were medically cleared, highlights a possible knowledge deficit in areas such as first aid knowledge and concussion management. Further research in these areas is warranted.

CHAPTER 13: FIRST AID AND CONCUSSION KNOWLEDGE OF RUGBY LEAGUE TEAM MANAGEMENT, ADMINISTRATORS AND OFFICIALS IN NEW ZEALAND

This chapter comprises the following paper submitted to *New Zealand Journal of Sports Medicine*.

Reference

King, DA., Hume, & Clark, T. First aid and concussion knowledge of rugby league team management, administrators and officials in New Zealand. *Submitted to New Zealand Journal of Sports Medicine*

Author contribution

King, D. 82%; Hume, P. 15%; Clark, T. 3%

Overview

The aim of this study was to assess rugby league team management, administrators and officials' knowledge of first aid, concussion recognition and management and injury prevention. A descriptive study was conducted using a first aid and concussion knowledge questionnaire consisting of two parts: (1) Thirty six multi-choice questions on first-aid assessment and knowledge incorporating five constructs (injury prevention, identification and management, cardiopulmonary resuscitation, and wound care) and, (2) Thirty eight closed- and open-ended questions on concussion recognition, management and prevention knowledge. Ninety five people from a New Zealand Rugby League zonal region completed the questionnaire. Fifty two (55%) of respondents had a current up-to-date first aid certificate which included cardiopulmonary resuscitation. Only two (2%) participants achieved the 80% passing score in the first aid and concussion knowledge questionnaire. The mean ±SD percentages for the first aid knowledge questions was 56 ±13% and for the 16 symptom recognition of concussion questions was 33 ±14%. Overall sports-related concussion knowledge was low (42 ±20%). Loss of consciousness was reported to be incorrectly required for a concussion to have occurred by 39% of respondents. Of concern is that nearly half the respondents identified that all concussions recover at the same rate. All referees reported having a refereeing qualification while only 24% of coaches, 7% of managers and 2% of trainer/medics reported having a rugby league specific qualification. The first aid and concussion knowledge results highlighted a lower understanding of sports-related first aid and concussion than previously reported. Injury prevention and care programs in rugby

league at the amateur level in New Zealand should stress first aid and concussion injury knowledge management to enable knowledge empowerment.

Introduction

Originating in the north of England in the 1890's, rugby league is a full contact collision sport participated in countries throughout the world.[159] The game is played over two halves of 30 to 40 minutes duration depending on whether the level is junior, amateur, sub-elite or elite.[159] Players compete in a physically challenging contest that typically involves bouts of high-intensity activities (e.g., sprinting, running, passing, and tackling) separated by short bouts of low-intensity activities (standing, walking, jogging).[78] As a result of these activities musculoskeletal injuries occur frequently.[159]

In a study looking at the Accident Compensation Corporation related costs for rugby league injuries, the mean cost per moderate to severe injury entitlement claim (MSC) was NZD$7,100.[157] When reported by injury types, the most common injury entitlement claim was for soft tissue injuries (47%) accounting for nearly half of the costs (41%).[157] Concussions were less, accounting for 2% of all MSC's and 6% of MSC total costs, but alarmingly were the highest single injury type cost per claim at $25,347 per concussion MSC.[157] The number and costs of injuries in rugby league[157] highlights the need for first aid training in specific areas such as soft tissue injuries and concussion.[166] Due to this situation it has been recommended that all coaches should be trained in first aid.[8]

Sports injuries are the single-most commonly reported reason why people withdraw from sporting activity and participation.[54] This usually occurs as a result of the situation where a player gets injured at the amateur level and it is left to untrained personnel to treat the injured player at the sideline.[215] Often this role is left to the coach of the team to provide this care and this may be beyond their level of knowledge or training.[215]

Studies assessing first aid knowledge of coaches have shown low knowledge levels (between 27%[22] to 38%[215]) despite the majority of coaches (89%[22] to 93%[215]) having a current first aid certificate. When coaches were assessed for their knowledge and management of sports related concussion, 16%[191] to 51%[242] of coaches were unable to correctly identify factors relating to concussion recognition, management and prevention techniques. Of concern was that 42% of coaches thought that a player had to have loss of consciousness for a concussion to occur and

26% would return a player to participation while showing symptoms of a concussion.[242] All of these studies have been conducted in the United States of America where there are state legislated requirements for team management to have a current in-date first aid qualification as part of their coaching role within the sporting environment. To date there are no studies on team management first aid knowledge outside of the United States of America. This study endeavoured to assess the level of understanding of local rugby league club administrators, coaches and other team management about their knowledge of first aid, concussion recognition and management and injury prevention.

Methods

A descriptive questionnaire study was conducted during the off season period (November 2009 to February 2010) of the rugby league competition to assess rugby league team management, administrators and officials' knowledge of first aid, concussion recognition and management and injury prevention.

Participants

The 95 participants were from a New Zealand Rugby League zonal region and consisted of team coaches, managers, trainer/medics, club committee personnel and referees. Participation in the study was completely anonymous and voluntary. All procedures were approved by the Health and Disability Central Regional Ethics Committee (CEN/09/56/EXP).

Questionnaire

The first aid and concussion knowledge questionnaire consisted of three parts: Part I consistent of general information about the participants in terms of their role in rugby league and their qualifications and experience in first aid; Part II "first-aid knowledge" consisted of 36 multi-choice questions on first-aid assessment and knowledge incorporating five constructs (injury prevention, identification and management, CPR, and wound care); and Part III "concussion recognition, management and prevention knowledge" consisted of 38 closed- and open-ended questions on concussion recognition, management and prevention knowledge.

The part II questions were based on the New Zealand St John's First Aid, Sports Medicine New Zealand Sports Medic and New Zealand Resuscitation Council CPR exams.[22, 215] Based on a first aid knowledge questionnaire initially developed in 1986,[218] the part I first-aid and assessment and knowledge questions were updated to reflect changes in the American Red Cross First Aid exam and the American Red Cross Cardiopulmonary Resuscitation exams through several studies.[22, 215, 217]

The part III questions were based on previously published concussion assessment questionnaires relating to concussion recognition, management and assessment and incorporating the latest concussion consensus statement.[174, 191, 233] The concussion recognition, management and prevention knowledge questions were presented in two sections: (A) Concussion understanding; and (B) Concussion recognition, management and prevention. The concussion understanding questions were from a previously published[233] 22-item questionnaire designed to source information on the participants' knowledge about the signs and symptoms of a concussion, knowledge of return-to-play strategies and protocols, and their beliefs regarding medical follow-up and sport participation after a concussion. The concussion recognition, management and prevention questionnaire was originally developed for use with youth coaches.[242] The recognition questions included a list of 16 signs/symptoms, and the participants were asked to pick those they thought were actual sequelae of concussion. Lastly all participants were asked to respond to four true/false questions regarding concussion management. A check box was included that allowed participants to indicate that they did not know whether the statement was true or false to discourage them from guessing.

The current first aid and concussion knowledge questionnaire was reviewed and updated by two experienced first aid instructors to ensure the answers were in alignment with current practice. The pass mark of 80% used by first aid training organizations was kept to enable comparisons with other studies on first aid and concussion knowledge.

Analysis

The results of the first aid and concussion questionnaire were entered into an Excel spreadsheet and analysed with SPSS v.16.0 (SPSS Inc, Chicago, Illinois, USA) and the VRP Injury Statistics Software (http://www.iprc.unc.edu/sportsinjurystatistics.shtml). The reliability or internal consistency of part II and part III of the first aid and concussion knowledge questionnaire were assessed by estimating Cronbach's alpha coefficient. Data are reported as means with standard deviations ±SD.[240] Chi-squared (χ^2) analyses were performed to test for significant relationships between responses (correct or incorrect) for each construct. Significant p values reported in the text are less than 0.001 if they are not specifically stated.

Results

A total of 95 people (50 coaches, 13 managers, 15 trainer/medics, 14 club committee personnel and 3 referees) from the district rugby league community completed the questionnaire. The mean age of the participants was 38 yrs ±10 yrs. Males (83%) participated more than females (17%). Fifty two of respondents (55%) reported having a current in-date first aid certificate which included being certified in cardiopulmonary resuscitation. Only 54% of coaches reported that they had a rugby league coaching qualification, 54% of managers had a rugby league manager's qualification, 13% of trainers had a rugby league trainer's qualification and 100% of referees reported having a rugby league referee qualification.

First aid knowledge

The first-aid knowledge questions had a Cronbach's α of 0.79 which means that this section of the questionnaire had acceptable to good internal reliability.[108] The mean score for part II was 56 ±13% with the scores ranging from 24% to 84%. Only 2% of participants met the 80% pass mark (see Table 66). Significantly more trainer/medics had a current first aid certificate (χ^2=5, df=1, p=0.020) but they recorded a lower mean first aid knowledge score (57% vs. 60%) when compared with trainer/medics that did not have a current first aid certificate.

Table 66: Rugby league management role, qualification, first aid certificate, pass percentages, mean (±SD) first aid knowledge score for total, current first aid certificate and no current first aid certificate.

Role	Qualification %	First Aid Certificate %	First Aid Knowledge pass %	First Aid Knowledge score %	First Aid Knowledge Score (first aid certificate) %	First Aid Knowledge Score (no first aid certificate) %
Coach (n=50)	28	48	0.0	57 ±14	63 ±12	52 ±13
Manager (n=13)	7	62	0.0	56 ±14	49 ±15	66 ±3
Trainer/Medic (n=15)	2	80*	13	57 ±15	57 ±16	60 ±11
Club committee (n=14)	3	43	0.0	51 ±12	54 ±12	49 ±12
Referee (n=3)	100	67	0.0	57 ±2	57 ±2	55 ±0
Average ±SD				**56 ±13**	**58 ±14**	**53 ±13**
All respondents (n=95)	**50**	**55**	**2**			

Percentages are of total and individual management or official role. * =Significant difference (p<0.05) when compared with no current in-date first aid certificate.

The majority of participants were involved in senior rugby league (34%). No managers or trainer/medics were involved in mini-mod or women's rugby league activities (see Table 670).

Table 67: Distribution of participation group in rugby league by role in percentages.

	Mini-Mod	Age Grade	Senior	Women's	Premier	National
Coach (n=50)	24	12	30	5	26	3
Manager (n=13)	0	19	50	0	25	6
Trainer/Medic (n=15)	0	7	43	0	36	14
Club committee (n=14)	0	0	36	24	29	0
Referee (n=3)	13	13	13	13	13	36
All respondents (n=95)	**14**	**11**	**34**	**8**	**26**	**7**

Percentage of total and individual management or official role.

When comparing responses of all participants there were significant differences in the percentage of correct responses for the five construct areas of the first aid questionnaire (injury prevention χ^2=155, df=4; injury knowledge χ^2=14, df=4; injury management χ^2=9, df=4, p=0.004; cardiopulmonary resuscitation χ^2=9, df=4, p=0.003; wound care χ^2=70, df=4) (see Table 68).

Table 68: Percentage of correct responses by first aid knowledge construct for total participants, team management and officials.

	All respondents (n=95)	Coach (n=50)	Manager (n=13)	Trainer/Medic (n=15)	Committee (n=14)	Referee (n=3)
Construct						
Injury Prevention	**71***	69*	74*	79*	72*	67
Injury Knowledge	**44***	48	49	39*	33*	52
Injury Management	**45***	46	49	46	39*	37
Cardiopulmonary resuscitation	**42***	47	46	32*	36*	33
Wound Care	**69***	75*	65*	76	73*	93*

Percentage of total and individual management or official role. * =Significant difference (p<0.05) when compared with incorrect responses.

Team management with a current first aid certificate recorded a higher percentage of correct answers in most, but not all, of the five constructs of the first aid knowledge section of the questionnaire (see Table 69).

Table 69: Percentages of first aid knowledge five constructs responses by participants' role and first aid certificate.

	Injury Prevention		Injury Knowledge		Injury Management		CPR		Wound Care	
First aid certificate	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Coach (n=50)	69	68	60	50	52	40	63	33	76	58
Manager (n=13)	78	67	46	56	42	60	28	75	38	83
Trainer/Medic (n=15)	81	70	48	57	46	44	31	33	57	89
Club committee (n=14)	69	75	52	39	44	35	38	34	64	56
Referee (n=3)	67	56	60	50	33	44	25	50	100	67
All respondents (n=95)	**73**	**67**	**53**	**50**	**44**	**44.7**	**37**	**45**	**67**	**71**

Percentage of total and individual management or official role.

Concussion recognition, management and prevention knowledge

The Cronbach's α for the concussion recognition, management and prevention knowledge questions was 0.86 which means that this section of the questionnaire had good to excellent internal reliability.[108] All respondents reported that they knew what the term concussion meant and that concussions were more serious than other typical sports injuries. Of all respondents, 75% reported they knew how to recognize a concussion in players but only 58% reported they had discussed the consequences of a concussion with players. The majority (85%) identified that playing while recovering from a concussion could lead to long term complications.

More than half (54%) of the participants reported that they knew of a concussion policy in rugby league but only 8% could identify the three week stand-down requirement. The majority (78%) reported a seven day stand-down as the requirement for recovery from a concussion. More than half (55%) of participants who had had a player with concussion (n=52) reported that they had not sought a medical clearance for a concussed player before returning them to match or training activities. Trainer/medics reported more sequale symptoms of a concussion occurring (43% ±20%) than other team management. For all participants there were only 33% ±14% correct responses (see Table 70).

Table 70: Percentages of participants' responses to symptoms they thought were the sequale of a concussion occurring (concussion symptoms are indicated in bold).

Symptom	All respondents (n=95) %	Coach (n=50) %	Manager (n=13) %	Trainer/ Medic (n=15) %	Committee (n=14) %	Referee (n=3) %
Abnormal sense of smell	58	50	62	67	71	67
Abnormal sense of taste	33	30	46	33	29	33
Amnesia (loss of memory)	**37**	**30**	**46**	**53**	**36**	**33**
Blurred vision	**44**	**52**	**23**	**73**	**7**	**33**
Black eye	19	20	8	27	21	0
Chest pain	26	26	15	53	14	0
Confusion	**46**	**54**	**54**	**40**	**7**	**100**
Dizziness	**45**	**54**	**23**	**67**	**14**	**33**
Headache	**48**	**54**	**23**	**67**	**36**	**33**
Loss of consciousness	**39**	**54**	**15**	**33**	**14**	**33**
Nausea	**40**	**36**	**54**	**47**	**29**	**67**
Nosebleed	17	16	15	27	7	33
Numbness/Tingling upper extremity	18	20	8	7	21	67
Sharp burning pain in neck	19	18	31	20	7	33
Sleep disturbances	**26**	**26**	**46**	**27**	**7**	**33**
Weakness of neck range of motion	13	12	8	20	14	0

Percentage of total and individual management or official role.

The wearing of headgear was reported to aide in preventing concussion by more than half of all respondents (53%). More trainers (80%) supported this statement than coaches (62%) and managers (54%). Loss of consciousness was reported to be required for a concussion to have occurred by 39% of responses (see Table 71).

Table 71: Responses of team management to the true false questions on concussion by percentage.

	A concussion only occurs when the athlete loses consciousness (blacks out). **(False) %**			A concussion requires immediate removal from the game or practice. **(True) %**			A player who reports having a headache after a concussion will likely demonstrate other signs. **(True) %**			A player who displays any sign or symptom of concussion should not be allowed to return to play. **(True) %**		
	True	**False**	**DK**	**True**	**False**	**DK**	**True**	**False**	**DK**	**True**	**False**	**DK**
All respondents (n=95)	39	54	7	62	26	12	54	32	15	68	21	11
Coaches (n=50)	42	50	8	62	26	12	58	32	10	62	22	10
Managers (n=13)	15	77	8	39	39	23	23	54	23	69	23	8
Trainer/Medics (n=15)	53	47	0	93	7	0	73	13	13	93	7	0
Committee (n=14)	36	50	14	50	43	7	43	36	21	36	36	29
Referee (n=3)	33	67	0	67	0	33	43	36	21	100	0	0

Percentages round and may not equal 100. DK= don't know.

The overall sports-related concussion knowledge was low at 42% ±20% (see Table 72). The trainers/medics recorded the highest overall sports-related concussion knowledge with 51% ±26%.

Table 72: Percentage (±SD) of concussion knowledge overall, concussion recognition, management and prevention questions reported correctly by all respondents, team management, administration and official's.

	Overall %	Recognition %	Management %	Prevention %
Coach (n=50)	46 ±20	59 ±21	40 ±16	38 ±17
Manager (n=13)	33 ±23	41 ±31	28 ±18	29 ±18
Trainer/Medic (n=15)	51 ±26	71 ±25	49 ±21	34 ±20
Club committee (n=14)	26.±21	42 ±40	27 ±29	10 ±12
Referee (n=3)	47 ±37	71 ±41	50 ±31	20 ±17
All respondents (n=95)	**42 ±20**	**56 ±23**	**38 ±14**	**32 ±15**

Percentage of total and individual management or official role.

Overall scores for the first aid and concussion knowledge questionnaire

Half of the respondents reported they had a role specific rugby league qualification. More than half (55%) of respondents had a current in-date first aid certificate. Only two respondents achieved the 80% passing score on the first aid knowledge questionnaire (2%). All respondents reported that they had heard of the term concussion and 75% identified that they would be able to recognize if a concussion had occurred. All respondents reported that a concussion was more serious than other sports injuries but only 98% responded that sports-related concussion could influence players' social and work activities. Nearly all respondents reported that continuing to play with concussion symptoms could lead to serious health consequences (85%). This was similar for respondents concern if players continued to participate in sports activities with concussion symptoms (85%). The majority of respondents (70%) identified that they would insist a concussed player should see a doctor before returning to play or train while 26% of non-coaches would check with the coach before they could return a player to play or training. More than half of respondents (65%) knew of a guideline for concussion management but only 40% knew the three week stand down and medical clearance policy of New Zealand Rugby League.

Discussion

The purpose of this study was to assess rugby league team management, administrators and officials' knowledge of first aid, concussion recognition and management and injury prevention. No coaches were able to achieve the pass score in first aid knowledge and this could have serious consequences in regards to the safety of players in terms of appropriate first aid care on the field should a medical situation occur. Nearly a quarter of coaches surveyed (24%) reported they were involved in the mini-modified rugby league level of participation and they were the only team management personal reported to be involved at this level of participation. The knowledge of these coaches would ideally be higher than identified as they are often the only team management at matches should first aid decisions be required.

The first aid knowledge of team management, administrators and officials was lower than that previously reported for high school coaches (27%[22] to 38%[215]) in the United States of America. Only 55% of respondents had a current, in date, first aid certificate which was less than some (89%[217] to 93%[215]) but not all (12.4%[22]) previously published studies reporting first aid knowledge of sports support personnel. Given that only half the participants had formal first aid training it was expected that the knowledge on the various constructs in the first aid knowledge questionnaire would be 55% at best, and this was indeed the case for most constructs. Not recorded in this study was whether participants had undertaken any formal first aid training. As previously shown managers and trainer/medics had a higher mean first aid knowledge score for those reporting not having a current first aid certificate than those with a current in-date first aid certificate. Previous experience, participant occupation or exposure to first aid type environments may have influenced the results reported and these data should be included in any subsequent studies on first aid knowledge.

A possible reason for low scores for those that had a current certificate but did not provide the correct response may be that those who undertake formal first aid training may be learning the information to pass the course examination but not retaining the information well enough to be competent to provide sideline first aid. The retention of first aid knowledge was not formally undertaken and is seen as a limitation to this study. Although coaches and club administrators with a current first aid certificate recorded higher scores in the five constructs than those that did not have a current first aid certificate, managers, trainer/medics and officials without current first aid certificate scored higher in most of the five constructs than those who had a current first aid certificate. A recommendation for future studies would be to conduct pre and post first aid training questionnaires to see how much knowledge is retained.

Having a first aid certification did not mean that there was a greater knowledge base in first aid. In many areas participants without a first aid certificate had a higher percentage of correct responses than those with a first aid certificate. Not recorded in this study were the participant's experiences with first aid situations or whether they had been exposed to environments where first aid or similar activities occur frequently. Another factor to be considered when reviewing the results of this study is nervousness. In a similar study[22] it was reported that participants undertaking the first aid knowledge questionnaire were observed to be nervous. A possible consequence of this nervousness is transference resulting in a lowered first aid knowledge score.[22] Although this is a possible situation for the resulting low score it does not account for 98% of participants not achieving the 80% pass mark.

Qualifications in first aid are not the only concerning issue in this study. Role specific qualifications were reported to have been attained by only half (50%) of the respondents. Injury prevention is just as important as first aid[22] and is part of the New Zealand Rugby League team management specific courses. Team management who do not have the role specific qualifications may not have the latest injury prevention knowledge that is part of these courses. As a result coaches, and trainer/medics, may be placing the players at undue risk by the way they conduct the training or match activities or by the way they manage injuries that occur in these environments. Coaches and trainer/medics with no formal qualifications may also rely on previous training activities to train the players which may include at risk activities or unsafe drills.[22] For example, having players do prolonged repetitive movements (drills) may place the player at risk of an overuse injury.[22] These types of injuries often require prolonged periods of rehabilitation with other health professional input to heal appropriately. Another example is coaches may use water breaks as a reward for positive team training results. As a result of this, if the team training is not going well players may become dehydrated and at risk of heat injury. This was highlighted by the results of the first aid knowledge question “Heat stroke is best prevented by…” with only 37% of participants responding with the answer “unlimited water breaks”.

Injury prevention for concussion is also a concern in this study with more than half of the participants reporting that head-gear aids in the prevention of concussion. In addition nearly a quarter (22%) of participants reported that mouth-guards prevented concussion and nearly half (39%) reported that concussion only occurred when a player loses consciousness. This was similar for the stand down period of a concussion with only 40% of participants responding to a 21 day stand down while 45% responded that all players recover at the same rate from a concussion. These results highlight a lower understanding of sports-related concussion than previously reported (42% vs. 62%[242] vs. 84%[191]) and highlight areas that should be addressed in possible future targeted concussion injury prevention programs.

The findings of this study highlight some of the misconceptions that are common in the population generally. Loss of consciousness was reported to be required for a concussion to occur by nearly 40% of participants while 26% responded that removal from the field with a concussion was not required and 20% would let a symptomatic player return to play. This is similar to another study[242] that reported 42% of coaches thought that loss of consciousness was required for a concussion to occur, 32% would not remove a concussed player from the field of play and 26% would let a symptomatic player return to play. It is generally acknowledged in the concussion literature that loss of consciousness is not required for a concussion to occur and this symptom has a limited value in assessing concussion severity has occurred.[173, 174] Additionally it is recommended that any player with a concussion be removed from play and evaluated further.[173, 174] Signs such as headache, dizziness, nausea, brief amnesia, drowsiness feelings of being in a fog and visual disturbances are symptoms of a possible concussion and should be observed for in a suspected concussed player.[242] Finally it is a consensus amongst concussion recommendations that players should never return to play while still symptomatic.[174] These findings are a concern and highlight the need for further concussion education to occur for all people involved in rugby league at the management level of participation, and for sport in general.

More than half of the participants in this study responded that head-gear aids in the prevention of concussion which was similar to other studies that have reported over 50% of players believing that head-gear could minimize the risk of concussion in rugby union.[65, 200] Only 38% of coaches responded to this statement which is also consistent with another study[200] that reported only 33% of the coaches provided their attitudes towards head-gear and concussion. Head-gear has been professed to have protective capabilities and theoretically reduce head related injuries.[176] In sports such as ice hockey and American football there is inconsistent evidence that sport-specific head-gear has protective qualities.[176] Unfortunately there are currently no rugby specific headgear that has been shown to be beneficial in reducing the rate of concussion. Most commercially available soft head-gear allowable under the rules of rugby league and union fail impact testing criteria that is similar to the force required for a sports-related concussion to occur.[175, 250] Better education and dissemination is warranted to further educate coaches, and players, on the protective role of headgear. This may assist in dispelling beliefs that head-gear will assist in protection from concussion.

Of concern is the finding that nearly half of the participants identified that concussions recover at the same rate as other injuries. Recent literature has identified that the criteria for adults returning from a concussion should be different from children and adolescents.[61, 163, 174] In the Zurich concussion consensus statement,[174] it was identified that adolescents (less than 18 yrs old) and children down to the age of 10 yrs old should be managed more conservatively than adults. This includes the use of the return to play guidelines which may require a longer period of rest and non contact activities than adults with a concussion.[174] Children under the age of 10 yrs old should be assessed and managed medically as they require more age-appropriate assessments and should not commence any return to play until clinically symptom free from a concussion.[174] Females have a longer prolongation post-concussion reaction time and greater symptom severity than males[32, 143, 163] and are at a greater risk for a concussion to occur[47, 49] although evidence is limited but suggestive that gender variations in the management of concussion is important.[163] There is also evidence in the paediatric population that concussed girls report a significantly higher mean symptom score than boys on initial presentation.[25] These findings support the recommendation that a "one-size fits all" policy for the management of concussion should not be undertaken and the need for an individualized approach is important.[39]

Although this study was conducted at the amateur level of rugby league participation where it is totally reliant on volunteers, there is still a requirement for people in this role to undertake and complete knowledge empowerment courses in regards to sports-related concussion programs. Volunteers involved in any level of sports in any role have a responsibility to ensure that the decisions they make in regards to injuries and concussion enable the most appropriate care to be provided. In the case of sports-related concussion it is better to stand the player down than to risk them further by allowing them to participate in activities where they could be further harmed. A tool developed for assisting people involved in sports where concussions may occur has been produced by the Accident Compensation Corporation. The sideline concussion card is designed to provide temporary interim management guidelines for a suspected concussion, encouraging players to seek medical treatment.[110] The sideline concussion card is based on a similar card utilised by the University of Pittsburgh that incorporates 'Maddocks questions',[171] as well as 'anterograde' and 'retrograde' questions shown as another predictive ways of assessing concussion.[40] Aspects of the sideline concussion card have been incorporated into the recently produced Sports Concussion Assessment Tool, developed for trained medical personal.[173] It is recommended that injury prevention programs, incorporating concussion recognition, management and prevention, should be provided to all team management, administrators and officials on a regular basis with a requirement for them to update regularly as part of their role in the sport.

Conclusion

The first aid and concussion knowledge results highlighted a lower understanding of sports-related first aid and concussion than previously reported. Injury prevention and care programs in rugby league at the amateur level in New Zealand should stress first aid and concussion injury knowledge management to enable knowledge empowerment.

CHAPTER 14: SUMMARY/CONCLUSIONS

Rugby league is an international collision sport played by junior, amateur, semi-professional and professional players. The number of published studies in rugby league is small but the ongoing research is aiding in broadening the knowledge of the relationships between player characteristics and aspects of the tackle with rugby league injury and performance. The research in this thesis aimed to assist in broadening the knowledge base of rugby league by conducting a series of studies focused on: (1) The costs, site, type and severity of injuries to amateur rugby league participants via epidemiological analyses of longitudinal data; (2) The relationship between anthropometric characteristics of rugby league participants with rate of injury via a longitudinal study; (3) The nature, type, site and direction of collisions and collision-related injuries via a video analysis study; (4) The return to play decisions of injured amateur rugby league participants via a cross sectional survey study; and (5) The knowledge of first aid and concussion management of rugby league support personnel via a cross sectional survey study.

The epidemiology of rugby league injuries and associated costs in New Zealand requiring medical treatment were examined (Chapter's 4 to 8) using the New Zealand national Accident Compensation Corporation injury data for the period 1999 to 2007.

In Chapter 4, data were analysed by demographics, body region, nature/severity of injury, and medical procedure and costs. A total of 5,941 injury entitlement claims were recorded over the study period with a significant decrease observed in the injury rate between the 1999-00 and 2002-03 reporting years. The total cost of the injuries for the study period was $42,822,048. The mean ±SD number of injury entitlement claims per year was 743 ±271 and yearly cost was $5,352,760 ±$2,485,535. The knee was the most commonly reported injury site (225 per 1000 entitlement claims; $8,750,147) and soft tissue injuries were the most common injury types (474 per 1000 entitlement claims; $17,324,214). Accounting for only 2% of total injury entitlement claims, concussion/brain injuries accounted for 6% of injury entitlement costs and had the highest mean cost per claim ($25,347). The upper and lower arm recorded the highest mean injury site claim cost of $43,096 per claim. The 25-29 age group recorded 28% of total injury entitlement claims and 30% of total injury entitlement costs which was slightly more than the 20-24 age group (27% claims; 25% costs). Nearly 15% of total MSC injury entitlement claims and 20% of total costs were recorded from participants 35 years or older.

The study identified that the knee was the most common injury site and soft tissue injuries were the most common injury type requiring medical treatment, which is consistent with other international studies on rugby league epidemiology. This study also highlighted that both the rate of injury and the average age of injured rugby league players increased over time. The high cost of concussion/brain injuries is a cause for concern as it reflects the severity of the injuries.

Injury prevention programmes for rugby league should focus on reducing the risk of concussion/brain injury and knee and soft tissue injury, and should target participants in the 20-30 year age range. More longitudinal epidemiological studies with specific details on injury mechanisms and participation data are warranted to further identify the injury circumstances surrounding participation in rugby league activities.

In Chapter 5 data were analysed by ethnic groups for demographics, body region, nature/severity of injury, and medical procedure and costs. It was identified that New Zealand Maori accounted for 40% of the number of total injury claims and 44% of the total injury entitlement costs but were recorded as only 13% of the total New Zealand population. Accounting for only 3% of the population distribution living in Auckland, New Zealand Maori recorded 12% of the total injury claims in the Auckland district. Soft tissue injuries accounted for 11 ±9% of injury claims and 8 ±7% of injury entitlement costs for all ethnic groups. New Zealand Maori recorded more injury claims for the knee than all other ethnic groups. Injury claims for New Zealand Europeans recorded more trade occupations, New Zealand Maori more plant and machinery occupations and Pacific peoples more elementary occupations. New Zealand Maori recorded significantly more injury claims for both males and females than all other ethnic groups over the study period.

The study identified the number of injury claims, and associated costs of the injuries, by ethnic group that have occurred from participation in rugby league activities in New Zealand over an eight year period. NZ Maori are disproportionately participating in rugby league in NZ, but the proportions injured are consistent with reported proportions playing the game. Further research is warranted to fully explore the differences in injury rate between the ethnic groups and to what extent these differences in levels of participation in rugby league activities.

In Chapter 6 women's rugby league injury data were analysed by demographics, body region, nature/severity of injury, and medical procedure and costs. There were 320 moderate to serious (MSC) injury claims recorded for females participating in rugby league activities over the study period. There was a mean ±SD of 38 ±10 injury claims per year. The mean cost per year for the study period was $196,514 ±$99,133 with half of the injury claims occurring in New Zealand Maori. Concussion / brain injuries accounted for 4% of total female MSC injury claims but accounted for 5% of female injury costs ($84,399) with the highest mean cost per claim ($7,033). The lower limb accounted for 65% of the total female injury claims and 59% of total injury costs ($922,296). The mean cost per claim was higher for the lower limb ($4,434) than the upper ($3,331) limb. Clerks recorded 16% of the total injury claims, 20% of total injury costs ($319,474) and had the highest mean cost per claim ($6,144). The 25-29 age group recorded 32% of injury claims and 34% of injury costs. The 35-39 age group recorded the highest mean cost per claim ($6,200) but only 11% of total claims and 14% of total costs.

When compared with other studies in rugby league injuries, it appears that females incur substantially fewer injuries (6%) than males (94%). Though no participation data by gender were available, it was likely that participation percentages were reflected in the injury percentages. The high frequency (65%) and cost proportion (59%) for lower limb injuries was higher in females than in male rugby league players (previously reported as 42% of the injury claims and 32% of the total injury claim costs for the lower limb). Injury prevention programmes for women's rugby league should focus on the 25-29 age group and address ways to prevent concussion and lower limb injuries.

In Chapter 7 a description of rugby league head, shoulder and knee injuries in New Zealand requiring medical treatment and associated costs was undertaken for rugby league injury entitlement claims. There were 565 head and neck (95 per 1000 injury claims), 1,006 shoulder (169 per 1000 injury claims) and 1,338 knee (225 per 1000 injury claims) total rugby league injuries. Concussions accounted for 70% of the total injury claims for the head. The knee being the most common injury site was consistent with other international studies on rugby league epidemiology. The high cost of concussion injuries is a cause for concern as it reflects the severity of these head injuries. Injury prevention programmes for rugby league should focus on reducing the risk of concussion injury along with knee and shoulder injury.

In Chapter 8 the New Zealand national Accident Compensation Corporation data were analysed for moderate to serious injury entitlement claims (MSC) in 1999 to 2008 for the number, rate, type and cost of neck, back and spine rugby league injuries resulting in medical treatment. There were 412 (6%) neck, back and spine MSC claims totalling $9,656,521 (16%) of the total injury entitlement costs for rugby league over the nine year period. The rate of MSC neck, back and spine rugby league injuries was 57 per 1000 total rugby league claims. There were significantly more soft tissue injuries than fracture-dislocations (χ^2=25.3, p<0.001) for neck, back and spine MSC claims, which is similar to previous studies. Although the rate of neck, back and spine injuries decreased over the nine years from 65 to 46 per 1000 injury claims, there was a significant increase in the number of neck, back and spine injuries (χ^2=36.7, p<0.001), and the mean cost per MSC injury (χ^2=9441.4, p<0.001) over the duration of the study. The frequency, severity and cost of neck, back and spine soft tissue and fracture injuries in rugby league is an issue that needs to be addressed. Coaches should ensure tackling technique is correctly taught to all players as part of the training program for rugby league participants. Team medical personnel should be trained in dealing with head, neck and spine injuries.

Some of the potential risk factors for rugby league injuries were examined (see Chapter's 5 to 14) using data obtained from various sources: (1) Comparison of anthropometric and speed characteristics of professional players with injury rate over a two year period; (2) Video analysis of 80 matches of international, National Rugby League and National Youth Competition matches for the nature and type of tackles; (3) Video analysis of professional rugby league players injuries in the tackle over a two year period; (4) Description of amateur players perceptions of reasons for their return to rugby league activities following a missed match injury; and (5) Assessing team management, administrators and officials first aid knowledge and concussion recognition, management and prevention knowledge.

In Chapter 9 the nature, height, site and direction of tackles seen in professional rugby league were described. A retrospective observational analysis was conducted using videos of 80 rugby league matches from 2008 (20 randomly selected international rugby league matches, 30 randomly selected National Rugby League competition matches and 30 randomly selected National Youth Competition matches). There were 50019 tackles recorded representing 701 ±64 tackles per match. Nearly 50% of tackles involved tacklers from behind the visual fields of the ball carrier, most tackles involved either two or three tacklers, most tackles involved contact with the mid-torso and hip-thigh region of the ball carrier. Significantly more players were involved in the tackle in the first, than the second half of matches (χ^2=4.3, df=1, p=0.038). Significantly more tackles were recorded in the defence than the attack side of the field (χ^2=183.1, df=1, p<0.001). Forwards were more commonly involved in the tackle than backs (χ^2=4050, df=1, p<0.001). Forwards were significantly more involved in tackle events than backs but when viewed in player groups, adjustables were involved in significantly more tackle events than outside backs (χ^2=5630, df=1 p<0.001) and hit-up forwards (χ^2=3280, df=1, p<0.001). Coaches should focus on getting players to practice correct technique during tackling with two or more tacklers and when tackling in the ball carriers blind vision area.

In Chapter 10 a total of 31655 tackles in 48 professional rugby league matches were coded from video for height and direction of tackle on the ball carrier. Injuries were recorded by team medical staff for injury date, time, site, type, mechanism, severity and for player position. Collision-related injuries were most frequently the result of two tacklers being involved in the tackling the ball-carrier from the side at shoulder or mid torso body levels. The ball carrier had a higher injury rate when tackled from behind their visual field at shoulder height and in the fourth quarter of matches. Tacklers had a higher risk of injury when tackling from the side of the ball carrier, as the first tackler, and in the third quarter of matches. Coaches should focus on getting players to practice correct technique during tackling with two or more tacklers and when tackling in the ball carriers blind vision area.

In Chapter 11 the effect of player positional groups on the nature of tackles that resulted in collision-related injuries in professional rugby league matches was described. A prospective observational epidemiology analyses for collision-related injuries and video analyses for the nature of tackles were conducted for a single team in the National Rugby League (NRL) throughout the 2007 and 2008 competitions for a total of 48 games. Risk ratios (RR) were calculated for comparisons between positional groups (adjustable, hit-up forwards or outside backs). The total missed match collision-related injury rate was 58 per 1000 player hours. Hit-up forwards recorded significantly more total collision-related injuries than outside backs (RR: 1.3; p=0.049), but not more than adjustables (RR: 1.0; p=0.922). Hit-up forwards recorded significantly more chest-back collision-related injuries than adjustables (RR: 6.0; p=0.008). Outside backs recorded significantly more tackle injuries as the ball carrier than the tackler (RR: 2.4; p=0.015) while adjustables recorded significantly more tackle injuries as the tackler than the ball carrier (RR: 1.8; p<0.001). Player positional group had an effect on tackle related injury type and injury site. Hit-up forwards and outside backs recorded more tackle related injuries as a ball carrier than as a tackler, while in contrast, adjustables recorded more collision-related injuries as the tackler than the ball carrier. Further research is warranted to determine if positional group specific training in the collision will assist in reducing the injury rate

In Chapter 12 the decisions for the return to play of players that missed training and/or rugby league matches as a direct result of an injury occurring from participation in rugby league activities was documented. A prospective experimental study was conducted to identify, document and report player perspectives on reasons they returned to participation in rugby league as a result of incurring a missed match or missed training injury from rugby league activities. A total of 63 people participated in the study having recorded a missed training and/or match injury from 178 training sessions and 85 matches. There were 20 training injuries (4 per 1000 training hours) and 73 match injuries (80 per 1000 match hours) that were recorded as resulting in missed training and/or match activities. The majority of injured players returning to play were in paid employment (73%) with 26% either unemployed or enrolled as a student and 1% self employed. Eighty percent of injured players saw a health professional as part of their rehabilitation process. The team coach was reported to have asked the player to return to rugby league activities in 28% of training return and 29% of match participation. More than three quarters of injured players felt that the recommended time off from training (75%) and match (80%) activities by health professionals were too long. The most powerful factor according to a third of all players was that being told they could return had the most significant influence on their decision. Of concern is that nearly a third also reported that the injury sustained was not as bad as first diagnosed. Therefore, it is crucial that players receive the best and perhaps more importantly the most qualified advice at the early stage of assessment to ensure correct treatment and ongoing management of their injuries**.**

In Chapter 13 a descriptive study was undertaken to assess team management, administrators and officials' first aid knowledge and concussion recognition, management and prevention. Ninety five people from a New Zealand Rugby League zonal region completed the questionnaire. Fifty two (55%) of respondents had a current up-to-date first aid certificate which included cardiopulmonary resuscitation. Only two (2%) participants achieved the 80% passing score in the first aid and concussion knowledge questionnaire. The mean ±SD percentages for the first aid knowledge questions was 56 ±13% and for the 16 symptom recognition of concussion questions was 33 ±14%. Overall sports-related concussion knowledge was low (42 ±20%). Loss of consciousness was reported to be incorrectly required for a concussion to have occurred by 39% of respondents. Of concern is that nearly half the respondents identified that all concussions recover at the same rate. All referees reported having a refereeing qualification while only 24% of coaches, 7% of managers and 2% of trainer/medics reported having a rugby league specific qualification. Of concern is the finding that nearly half of the responses identified that all concussions recover at the same rate. These results highlight a lower understanding of sports-related concussion than previously reported and highlight areas that should be addressed in possible future targeted concussion injury prevention enable retention of first aid skills and knowledge to occur. A recommendation for future studies would be to conduct pre and post first aid training questionnaires to see how much knowledge is retained.

Thesis limitations

The quality of the epidemiological studies contained in this thesis were dependant on the data quality utilised for analysis.[112] In Chapters 4 to 8, the data provided for the analysis was from the ACC database and is dependent on several data input factors:

(1) The correct data code being used on the data collection sheet.
(2) The occupational classifications provided were limited to just ten classifications as identified by the New Zealand Standard Classifications of Occupations.[128]
(3) The occupational classification was open for interpretation by the data operator at the data input stage i.e. a program manager can be classified as a professional, technical or administrator where as they may be a program manager for a trade worker, computer operator or elementary occupation.
(4) People going to a registered health professional for treatment of their injury.
(5) Underreporting of costs due to patients undertaking private medical care.
(6) People making a claim for the injury (there is no time limit on when a patient can make an acute injury claim to ACC).[112]

Additionally the data retrieved were protected to ensure client confidentiality by limiting the access to low level results under four injury claims. Therefore any data less than or equal to three injury claims were rounded to represent three claims only. The net result of these limitations may have seen a downwards bias in the injury entitlement claim incidence and, some of the calculations were not equal depending on the way the data were rounded.

Another limitation to Chapters 4 to 8 was that the data were limited to just the ACC database. Currently there is no other recording system available for analysis of rugby league injuries in areas such as:

(1) Numbers participating in rugby league activities.
(2) Age of players participating.
(3) Identification of the ethnicity of players.
(4) Number of matches played and trainings completed enabling match and training exposure hours.
(5) How the injuries occurred.

(6) What participation level the injuries occurred in.
(7) Whether the injuries occurred as a result of match or training activities.
(8) At what stage of the match or training activity the injuries occurred.

In reviewing the nature, site and height of tackles at the professional level of participation (Chapter 9) only one analyst reviewed all the tackles. With each match taking approximately five to six hours to review this necessitated nearly 500 hours to enable the data to be collected. Although the use one analyst ensured that the same definitions were consistent throughout the data collection process, there was no opportunity to have any inter-rater reliability tested nor was the study able to provide any Kappa values. The interpretation of the tackle was therefore left to the one analyst and this is seen as a limitation to the study. Future studies looking at complex situations such as the tackle in rugby league would benefit from more than one analyst reporting.

In Chapter's 10 and 11 the nature of injuries as a result of tackles in a professional rugby league team was reported. Data were obtained retrospectively and the limitation identified with this data was that the injury definition utilised for the recording of the injury may have been inconsistent throughout the study period. Although the same person collected the injury data, the recording criteria for documenting the data differed over the study period and more data were collected on the injury in the subsequent participation season. This may have lead to an under-reporting of the injuries in the first year of the study period.

In Chapter 12 the player perspective of the reasons for return to participating in rugby league activities was limited to amateur participants in one team over a two year period. The researcher was the team medic/trainer and is accredited in tertiary injury recognition, assessment and management which may have skewed the data recorded. No other team partook in the study and there were no other accredited team medic/trainers in the domestic competition. As a result of this the data presented may not be reflective of all amateur team participants' reasons why they returned to rugby league activities or of the actual missed match duration reported in this study.

Team management, administrators and officials first aid knowledge and concussion recognition, management and prevention were examined in Chapter 13. This study was undertaken on a small cohort (n=95) and therefore the results may not be reflective of the overall knowledge of team management throughout New Zealand. The study is limited by the small number of participants being undertaken in one district and not all team management, administrators and officials who are involved in rugby league were included.

Future directions

This thesis reported on several aspects of rugby league injuries and the most commonly reported cause of the injury in rugby league – the tackle. The published articles resulting from this thesis, combined with the political changes in rugby league in New Zealand, have seen discussions of the development of a research focus by New Zealand Rugby League. Further studies following on from the topics discussed within this thesis are recommended as follows.

- This thesis provided a review on the match and training injuries of rugby league participants at all levels of participation. Although this review covered all published studies to 2008 there was no published study on masters' rugby league participation nor referees match and training activities or injuries as a result of rugby league activities identified through any of the literature search databases. Future research would be beneficial for injury prevention programmes in both these areas.

- The cost, incidence and type of injuries that occurred as a result of participation in rugby league activities in New Zealand were reported in this thesis. Further ongoing analysis of ACC rugby league injury data in conjunction with longitudinal observational studies on the incidence of injury to rugby league participants in New Zealand is recommended. This research would ascertain whether there were any ongoing trends of participants at the different levels of participation (Masters, senior, age grade, junior and representative).

- The nature of the tackle reported in this thesis for the professional level of participation is likely to be different from tackles at amateur, women and junior levels of participation. Further studies in these areas would assist with injury prevention programs.

- This thesis provided some evidence on injuries that occurred as a result of the tackle. However the findings were limited to a single event and did not report what involvement the injured players had prior to the injury occurring. Further studies exploring the movement, distance travelled and previous tackle involvements of rugby league players involved in tackle-related injuries will assist in developing injury reduction techniques for tackles in rugby league.

- Some evidence on player decisions and influences when returning to rugby league participation from an injury that resulted in a missed match or training session was reported in this thesis. Further studies exploring the use of a questionnaire or assessment for the identification of player readiness for return to participation in rugby league activities is warranted. Tools that have been developed and used in other sporting activities such as the Recovery-Stress Questionnaire Sport (RESTQ-Sport),[145] RecoveryCue,[146] Injury-Psychological Readiness to Return to Sport (I-PPRS)[124] and the Re-Injury Anxiety Inventory (RIAI)[245] could be used in rugby league.

- The knowledge of first aid and concussion recognition, management and prevention is reportedly low in a single district in New Zealand. Further studies are warranted to compare pre-course and post-course knowledge of first aid, injury prevention and concussion recognition, management and prevention. These studies will assist in developing and tailoring injury prevention programs to enable knowledge empowerment.

Practical outcomes as a result of this thesis

Practical outcomes as a result of the findings reported in this thesis are provided for consideration at all levels of rugby league administration, education and participation.

For rugby league coaches at all levels of competition:

- That, as part of the coach education program, all rugby league coaching qualifications have a two to three year renewal process.
- That, as part of the ongoing coach education program, all rugby league coaches have, and maintain a current First Aid certificate that meets the New Zealand Qualifications Authority (NZQA) standards (6400, 6401 and 6402).
- That, as part of the ongoing coach education program, all rugby league coaches have, and maintain a annual “Tackle Safety” training certification to be eligible to coach a team at all levels of participation for the current year of certification. In addition the regional rugby league administration should maintain a registrar of all coaches recording the annual certification.

For team managers at all levels of competition:

- That, as part of the ongoing manager education program, all rugby league managers have, and maintain, a current First Aid certificate that meets the New Zealand Qualifications Authority

(NZQA) standards (6400, 6401 and 6402) in addition to the New Zealand Rugby League Managers certification.

For team Trainers/Medics at all levels of competition:

- That, as part of an ongoing trainer education program, all rugby league trainers have, and maintain a current First Aid certificate that meets the New Zealand Qualifications Authority (NZQA) standards (6400, 6401 and 6402).
- That all team trainers are certified to the appropriate level of qualification appropriate for the level of competition that they are associated with.
- That all team trainers undergo a two year rugby league trainer revalidation process to ensure that they remain current and up to date with trends and activities for player injury prevention.
- That all senior level trainers have, and maintain the appropriate sports medic qualifications as identified by the national rugby league body.
- That all senior levels trainers undertake, and maintain spine care management qualifications. At least one senior trainer/medic with the spine care management qualification should be available at club venues whenever a match is held there.

For all referees at all levels of competition:

- That, as part of an ongoing referee education program, all rugby league referees have, and maintains a current First Aid certificate that meets the New Zealand Qualifications Authority (NZQA) standards (6400, 6401 and 6402).

For club administrators / committee members:

- That all club administrators ensure all teams under their jurisdiction have currently in-date and appropriately qualified team management (Coach, manager, Trainer/Medic) for the current year of competition.
- That all club venues have certified and maintained spine care management facilities at every game held at the clubs designated home venue.
- That all club venues have an appropriately designed, designated first aid treatment room available at all home venue activities and this is used specifically for the care of injuries by appropriately trained personnel.
- That a medical emergency plan is established and implemented and that all team management personnel at all levels of competition are able to enact the medical emergency plan if, and when necessary.

For rugby league administrators / zone/district general managers:

- That all clubs, activities, competition and events under the jurisdiction of the zone, district or entity have appropriately designated, and trained, personnel who are available to coach, manage, train and provide first aid care for teams, competitions and activities under their jurisdiction.
- That the zone/district general managers implement, and maintain, a concussion register for all reported concussions that occur in the area of their jurisdiction.
- That annual coaching, manager and trainer courses are held in a timely manner to ensure that team management are available at the commencement of the competition to ensure all teams at all levels of competition have appropriately qualified team management personnel available.
- That no team / club / competition be allowed to participate or commence unless there are in-date, qualified coaches, managers and trainers with every team entered into the competition.
- That an international standard of trainer identification scheme is identified and implemented at all levels of competition to enable easy identification.

Summary

This PhD research has contributed knowledge regarding the understanding of the costs and characteristics associated with amateur rugby league injuries in New Zealand. For the first time the differences between ethnic groups site, types and injury associated costs were recorded. Female rugby league injury related costs and types were, for the first time, reported identifying the differences between genders that participate in rugby league activities.

The nature of tackles and tackle-related injuries were explored for the first time in this thesis and showed nearly 50% of tackles involved tacklers from behind the visual fields of the ball carrier, most tackles involved either two or three tacklers, most tackles involved contact with the mid-torso and hip-thigh region of the ball carrier. Tackle-related injuries were most frequently the result of two tacklers being involved in tackling the ball-carrier from the side at shoulder or mid torso body levels. The ball carrier had a higher injury rate when tackled from behind their visual field at shoulder height and in the fourth quarter of matches. Tacklers had a higher risk of injury when tackling from the side of the ball carrier, as the first tackler, and in the third quarter of matches.

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APPENDICES

Rugby League: Beginnings, injury definitions, injury incidence and anthropometric aspects

A technical report for New Zealand Rugby League

11th June 2008

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NEW ZEALAND RUGBY LEAGUE™

Overview

This technical report is provided to the New Zealand Rugby League Inc. as a summary of the literature published in the scientific community specifically on: (1) A brief history of rugby league; (2) Injuries as a result of participation in rugby league activities; (3) Anthropometric and physiological aspects of rugby league participants; and (4) Risk factors for injury in rugby league.

A brief history of rugby league

Rugby league in New Zealand can be seen to have been the catalyst for the establishment of the game internationally from the 1905 'All Gold's' tour through Australia, England and Wales. Primarily an amateur participation contact sport, rugby league has struggled to establish itself throughout New Zealand with rugby union attempting to thwart its progress through various measures. Although different to rugby union in the modern version, it can draw its roots from the game and, as a result of breaking away from rugby union, it has developed in New Zealand as a sport, as people saw it as a faster, skilful and entertaining form of rugby.

Injuries as a result of participation in rugby league activities

The extent of injuries that occur from participation in all levels of rugby league activities (e.g., professional, semi-professional, elite, sub-elite, amateur and juniors), both in match and training environments, has been identified from the available research. The injury rate typically increases in correlation to the participation level. The studies vary as to the most common injury sites reported but the head and neck; shoulder and knee are more frequently reported. Muscular injuries are the most common type of injuries, although junior rugby league studies have shown fractures to be more common. Injuries more commonly occur in the tackle than by any other mechanism. Typically the tackled participant is more frequently injured than the tackler and this occurs more frequently in the third quarter of both match and training situations.

Anthropometric and physiological aspects of rugby league participants

Similar to injury rate, the anthropometric and physiological capacities of rugby league participants and the physiological demands of rugby league participation generally increase as the participation levels increase. However, there is evidence that participant physiological capacities may deteriorate as the season progresses. This has been shown to occur with increases in skin fold thickness and some decrement reported in participants' maximal aerobic power and muscular power over a season. This occurs primarily when training loads are less and match loads and injury rates are at their highest. New tests are now being published identifying more match specific assessments in areas previously overlooked enabling a wider physical assessment base to be established on the rugby league participant.

Risk factors for injury in rugby league

Player fatigue and participant intensity have been suggested as contributing to the injury rate. There has been a significant correlation identified between match intensity and injury rates at the semi-professional level of participation. Studies have reported a higher injury risk for participants with slow 10- and 40-m sprint times and a low maximal aerobic power. Furthermore, participants that completed less than 18 weeks of training prior to sustaining their initial injury have been identified as having a higher risk of sustaining a subsequent injury.

Future injury research for rugby league activities

A study should be conducted on rugby league recurrent or subsequent injuries. This research could assist in the development, and implementation of injury prevention activities and policies. The socioeconomic effects of injury from rugby league participation on the amateur participant should be determined. The research could assist in the identification of resources to be available to participants injured from rugby league activities who derive their income from sources other than rugby league activities.

The injury rate of amateur New Zealand rugby league participants should be determined to enable development of a data base of New Zealand specific injuries that occur from participation in rugby league activities. This data could be utilised in an injury fact sheet available from the NZRL.

An injury fact (e.g., double sided A4 size) sheet should be produced for NZRL to distribute during coaching education course, and the material should also be placed on the NZRL web site. This fact sheet would outline the injury rate, site and type of common injuries, and highlight known risk factors.

Anthropometric and physiological aspects, and injury rates of women rugby league participants, should be determined. This data would assist in the identification of the injuries that occur in women's rugby league participation enabling unique resources to be developed for injury prevention interventions and as part of the data base for an injury fact sheet available from NZRL.

Junior rugby league injury rates over a broader participation base should be determined. This data would be part of a collaborative identification of junior rugby league injuries worldwide and also be used as part of the database for an injury fact sheet available from NZRL.

Anthropometric and physiological changes of New Zealand rugby league participants should be determined. This data would assist in the identification of the effects of participation in rugby league activities and enable inter-district comparisons to occur. The data from these types of studies would be able to be used as part of the world wide knowledge base on rugby league participants and as part of the information fact sheets available from the NZRL.

Introduction

Participation in rugby league activities in New Zealand is primarily at the amateur level, although there are now semi-professional and professional teams based in New Zealand. As in all sporting activities there is an inherent risk of injuries occurring and, rugby league has a high injury rate. Recent Accident Compensation Corporation (ACC) reports have identified that the injury rate for rugby league is increasing. This has socioeconomic ramifications in terms of familial support, social interactions and employment responsibilities. There are also the financial implications on the individual, the community, society and the government through areas such as lost income and rehabilitation associated costs. Awareness of the injuries that occur, the risks associated with participation in rugby league and possible risk reduction techniques that are being identified will assist in minimizing the severity of injuries that occur.

This technical report is provided to the New Zealand Rugby League Inc. as a summary of the literature published in the scientific community specifically on:

(1) A brief history of rugby league;
(2) Injuries as a result of participation in rugby league activities;
(3) Anthropometric and physiological aspects of rugby league participants
(4) Risk factors for injury in rugby league; and
(5) Future research in rugby league activities.

This technical report is part of the ongoing PhD research being undertaken by Doug King on rugby league through the Sport Performance Research Institute New Zealand at AUT University.

Part 1: A brief history of rugby league

Following the now historic meeting in 1895 at the George Hotel in Huddersfield, a schism ensued with the Rugby Football Union (RFU). This schism occurred when 22 clubs broke away from under the RFU control and established the Northern Rugby Football Union.[59, 125, 251] The development of the 'Northern Union' (NU) was the start of professionalism in sport. Under NU rules players were compensated for wages lost as a result of sports participation.[59, 125, 220, 251] The NU also implemented new rules resulting in changes such as: (1) the number of players reduced to 13 on the field; (2) elimination of the line out; (3) implementation of a different scoring structure; and (4) introduction of a 'play the ball' stopping the use of 'rucking' and 'mauling' for possession of the ball as in RU.[168] These changes developed further over time into the game now known as rugby league.[104] Played by both junior and senior level competitors, rugby league can be seen in countries such as Australia, New Zealand, Scotland, Ireland, France, Russia, United States of America, Wales, Papua New Guinea, Fiji, Samoa and South Africa.[27, 183] Participants range in age from six to sixty years in amateur (male[92, 151, 154, 213] and female[91, 150]), semi-professional [148, 149, 154] and professional (male[114, 117, 134, 195, 230]) level competitions.

Rugby league in New Zealand

In 1907 Albert Henry Baskerville, a postal clerk, organised a Professional All Black tour to go to England to play Northern Union rules against Northern Union sides.[59, 125, 251] Known as the "Pro-Blacks"[59, 125, 251] or "All Gold's",[220] the tour team of consisted of 27 players from around New Zealand, including nine current All Black rugby union internationals.[220] The team travelled to Australia and played three matches in New South Wales before heading to England with Australian Henry Herbert (Dally) Messenger who was invited to tour with the team.[220] Competing in 29 club based matches, three test matches and two international matches in England and Wales, the All Gold's returned to Australia leaving four players behind in England, having secured professional club contracts.[220]

Returning to Australia the All Gold's played three more club based matches before they played Australia in the first test match.[220] Following the win (11-10) by the All Gold's they travelled to Brisbane for the second test. Unfortunately while on route to Brisbane Albert Henry Baskerville developed a "chill" and subsequently died from complications.[220] Despite the loss of their team mate and friend, the team played Australia in Brisbane winning 24 -12 before departing back to Sydney for the third test.[220] Losing this test (14-9) the All Gold's headed back to New Zealand having brought Northern Union rules to the international domain in England, Wales and Australia.

The first rugby league match played in New Zealand occurred on Saturday 13th June 1908 at Wellington's Athletic Park.[59, 125, 220] Organised as a benefit match for the widowed mother of Albert Henry Baskerville, the match was promoted as "rugby as it is played in England".[125] The match was watched by between 6-7000 spectators and drew praise by newspapers as an improvement on rugby union rules, making for a more interesting skilful and much faster game.[125]

Following this match, groups of enthusiasts attempted to start the new game in towns and cities throughout New Zealand and, by the end of 1908 representative teams had been in organised in Southland, Otago, South Canterbury, Wellington, Taranaki and Auckland.[59, 125] A Maori team was also formed and they competed in matches in New South Wales and Queensland, Australia in 1909.[59, 125] The regional districts also formulated governing bodies to cater for the games in their districts.[59, 125] But it was not until 1910 that the national governing body, the New Zealand Rugby League was formulated.[59, 125]

The New Zealand Rugby Union reacted to the tour, its own player's defection and the development of rugby league in New Zealand in several ways.[59, 125] The first reaction was to disqualify players who partook in rugby league from any rugby union activity, building or sports ground. Rugby union also endeavoured to stifle the development of rugby league by trying to have municipally own sports grounds denied to rugby league.[59, 125] By pressuring municipal councils into believing that they would disqualify a ground as professional and not allow rugby union to be played there, some council's denied requests by rugby league clubs to play in municipal areas.[59, 125] Despite these endeavours, in the early year's rugby league developed as a sport, as people saw it as a faster, more skilful and entertaining form of rugby.

What is rugby league?

Rugby league is a team sport that consists of 13 players. Junior and amateur rugby league matches are typically (but not always) played under an unlimited interchange rule whereas professional/elite and semi-professional/sub-elite rugby league teams utilise a limited interchange rule. Up to 12 interchanges are permitted in these competitions. Each team is permitted six tackles with the ball and they must advance down the field into the opposition's territory and score a try.[87, 114, 118] The ball must be passed backwards but can be carried or kicked into the opposition's territory.[87, 118] At the completion of the six tackles, the ball is immediately given to the opposition team to commence their set of six tackles.[87, 114] The same players are therefore involved in both attack and defence.

The game is played under different rules depending upon participation age. Children aged less than nine years old play under mini-modified rules requiring only a half sized field to be played in. There is no-tackling, no kicking of the ball and no scrums contended in this age group.[43, 147] Children between the ages of 10 and 12 years old also participate in a modified rules version of the game. This requires that the matches are played on three-quarter sized fields, allow tackles to be made, have limited kicking and they can contest for the ball in a scrum as in the full version of rugby league.[43, 147] For participants over the age of 13 years of age, the game is participated under the international rules.

Similar to rugby union, the rugby league team consists of two main groups of participants (six forwards and seven backs) on the field and four reserves.[37, 84, 183] The demands on the participants vary according to the specific positions played[37, 84, 183] with forwards (prop n=2, hooker n=1, second row n=2 and lock n=1) more predominately involved in large numbers of physical collisions and tackles.[78] Backs (half-back n=1, stand-off n=1, centre n=2, wing n=2 and fullback n=1) spend more time in free running but are involved in tackles and collisions.[78] These are sometimes grouped into four subgroups reflecting positional commonality (i.e. props, hookers and halves, back-rowers and outside backs).[37, 104, 183] The demands placed on the participants vary according to the specific position played during match participation.[84, 122]

As with all sport, there is a risk of sustaining an injury when participating in rugby league activities. The game is intermittent in nature requiring participants to compete in a challenging contest. Player's competing in rugby league often undergo frequent bouts of high intensity activity (e.g., tackling, sprinting, running and passing) interspersed with short bouts of low intensity activity (e.g., jogging, walking and standing).[27, 44, 104, 180] As a result of the intermittent nature of the game, the physiological demands of rugby league are complex. Players are required to have maximal aerobic power, speed, muscular strength and power and agility developed appropriately to be able to compete in the match environment.[27, 44, 104, 180] As a result of the physical requirements and intense nature of the game, musculoskeletal injuries are commonly reported.[77, 87, 104]

Part 2: Rugby league injury

In New Zealand, the majority of rugby league participants are amateur in nature (i.e. they derive income from another source). This is similar for the majority of participants in other league playing nations. Therefore the majority of injuries that occur from rugby league participation are incurred by these participants. Although there have been many studies published looking at both match and training injures in rugby league conducted at various levels of participation (see Table 1), there are still several participation levels where no prospective injury epidemiological studies have been completed. There is a paucity of studies on amateur and junior levels of participation. There is an assumption that the findings of the epidemiological studies on professional participants translate to other cohorts of participants in other countries but this is yet to be tested.[31]

Table 1: Prospective rugby league epidemiological publications by country.

Playing population	Studies conducted on match injuries	Studies conducted on training injuries
Male Professional Tournament	• None	• None
Male Professional	• England[116, 117, 119-122, 134, 137, 230] • Australia[114, 195, 197, 223]	• None
Female Elite Tournaments	• New Zealand[150]	• None
Female	• None	• None
Male semi-professional tournaments	• None	• None
Male semi-professional teams	• Australia[74, 77] • New Zealand[153]	• Australia[76, 77, 80]
Male sub-elite tournament	• None	• None
Male sub-elite teams	• Australia[85]	• Australia[81, 97]
Male Amateur Tournament	• None	• None
Male Amateur teams	• Australia[69] • New Zealand[152, 169]	• New Zealand[151]
Masters Tournament	• None	• None
Masters teams	• None	• None
School-boy tournaments	• None	• None
School-boy team	• None	• None
School-girl tournaments	• None	• None
School-girl teams	• None	• None
Junior	• Australia[92, 213] • New Zealand[148]	• None
Sevens	• Australia[73] • New Zealand[154]	• None
Competition	• New Zealand[185]	• None
Review of injuries	• New Zealand[169] • Australia[78, 141] • England[118]	• None

Injury definitions

To fully understand the extent and nature of rugby league injuries it is necessary to consider the various injury definitions that have been used for collation and assessment of rugby league injuries. Studies on the incidence of sporting injuries have varied in two main areas. These are (1) the definitions utilised, and (2) the methodologies undertaken.[29, 57, 62, 123, 244] As a consequence of these variations between studies, the results and conclusions obtained often have some important differences.[57, 62, 78, 87, 123, 137, 197, 244] A fundamental process, and typically the first step behind the injury prevention process, is ongoing injury surveillance.[57, 63, 196, 244] However, inter-study comparisons may prove to be difficult due to the inconsistencies in the injury definitions utilised.

Van Mechelen et al.[244] and Finch[63] identified that ongoing injury surveillance is a fundamental process behind successful injury prevention. However this has proven to be elusive in major sports partially because of the difficulties in forming consistent injury definitions.[57] The lack of consensus between researchers has severely limited the ability to compare injury rates between countries.[196] Several team sports (cricket,[196] football/soccer[67] and rugby union[68]) have published consensus statements in an attempt to obtain more consistent and comparable results from studies undertaken in these sporting activities.

The definition of a sports injury has been a frequently discussed topic and, to date, there is no universally accepted injury definition for a sports injury.[29, 133, 155, 194] In the study of sports injuries, definitions are typically provided as operational criteria for the recording and reporting of injuries rather than as a theoretical definition.[68] These definitions usually are broadly based around the concept that *"bodily damage caused by a transfer or absence of energy"* is what causes injuries to occur.[68] This concept is useful in the clarification of whether an incident in rugby league should be recorded as an injury.

Studies on the incidence of injuries in rugby league are no different. These have suffered from inconsistencies in the injury definitions utilised (see Tables 2–4). As a result of these inconsistencies, comparison and determination of the injury incidence may be difficult to undertake.[123, 141] Variations reported in injury incidence are often the result of data obtained from a relatively small numbers of players and teams[118, 134] and, often over a limited time frame.[141]

Some studies on rugby league injuries have utilised a missed match injury definition while others have utilised a first aid or medical treatment injury definition. Consequently any recommendation of what the definition of an injury should be has been widely discussed and disputed.[133, 155, 194] To date there is no uniformly accepted injury definition for rugby league studies. The key issue to establishing the injury definition has been centred on what injuries should be actually recorded. As shown in Tables 2 - 4, some authors utilise a time-loss definition in the form of missed matches, while other authors use a total injury definition or a combination of both time-loss and non-time-loss injuries.[155]

The use of a time-loss definition directs attention to those injuries that are most likely to have direct consequences on participant's, their team and the club's performance.[236] The use of this definition understates the effects that non-time-loss injuries have on the health care system.[134] The time-loss definition also contains certain inaccuracies. An amateur player who trains only twice a week has a greater chance of recovering from an injury before the next training session than a sub-elite/elite level player who trains daily.[144] An injured player may participate in a training session but the participation level may be handicapped by the injury or they may be undergoing a modified training session.[144]

Recent attempts to establish a standard definition for rugby league injuries by researchers in the field of injury incidence have been unsuccessful.[133, 155] Although the researchers had published in rugby league injury surveillance, some of the contributing authors were not in favour of a definition that was all encompassing enabling non-time-loss injuries to be recorded. The definition for a rugby league injury of:

> *"Any pain or disability that occurs during participation in rugby league match or training activities that is sustained by a player, irrespective of the need for match or training time loss or for first aid or medical attention. An injury that results in a player requiring first aid or medical attention is referred to as a 'medical attention injury' and an injury that results in the player being unable to partake in full part of future training and/or match activities is referred to a 'time loss' injury."*[155]

was eventually agreed upon by the majority of the authors, but this also resulted in two of the contributing authors withdrawing from the group.[155] This definition will be utilised for the duration of the research being undertaken.

Table 2: Injury definitions for professional participation.

Reference	Level of participation	Injury definition used
Seward et al.[223]	Professional (8 teams, 3 grades, 1 year)	That which caused a player to be unavailable for selection in a match, or participation in a training session or any other injury which required specific medical treatment, other than routine conservative measures.
Gibbs[114]	Professional (1 club, 3 grades over 3 years)	That occurring during a game that caused a player to miss a subsequent match.
Estell et al.[58]	Professional (2 grades) and elite junior (4 teams) over 1 season	Pain, discomfort or disability arising during, or immediately after, as a result of, playing in a rugby league match.
Stephenson et al.[230]	Professional (1 club, 2 grades over 4 seasons)	The onset of pain or a disability that occurred while playing rugby league football.
Hodgson-Phillips et al.[137]	Professional (1 team over 4 seasons)	Pain, discomfort, disability or illness (new or recurrent) that the player acknowledged after participating in a rugby league related activity / game.
Gissane et al.[118]	Professional (pooled data from 4 prospective studies: Seward,[223] Gibbs,[114] Stephenson,[230] Gissane[116])	That requiring a player to miss the subsequent game.
Gissane et al.[119]	Professional (1 club, 9 seasons)	A physical impairment received during a competitive match that prevented a player from being available for selection to play in the next game.
Orchard[193]	Professional (1 club, 2 grades over 6 seasons)	That requiring a player to miss a subsequent game.
O'Connor[189]	Professional (100 players from 13 clubs)	An injury was recorded if there was: (a) pain and tenderness in the adductors or at the adductor bone-tendon junction; (b) pain and weakness on resisted adduction; and (c) the player was unable to complete training or a game and missed the following training session.
Orchard et al.[195]	Professional State of Origin from 2000 to 2006 (1 team, 3 games a year)	A match injury recurrence (for the State of Origin team) was defined as an injury to the same body part which had been medically assessed prior to the start of the match and which caused the player to miss subsequent games for his club after the Origin match

Table 3: Injury definitions for semi-professional participation.

Reference	Level of participation	Injury definition used
Gabbett[76]	Semi-professional (60 players over 1 season)	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during a training session or immediately after the training session.
Gabbett[77]	Semi-professional (156 players over 2 seasons)	Any pain or disability suffered by a player during a match or training session, and subsequently assess by the head trainer during or immediately following the match or training session.
Gabbett[81]	Sub-elite (220 players, 3 years)	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during, or immediately following the training session.
Gabbett[80]	Semi-professional (79 players, 1 year)	Any pain or disability suffered by a player during a match or training session, and subsequently assessed by the head trainer during or immediately after the match or training session.
Gabbett[84]	Semi-professional (156 players, 2 seasons)	Any pain or disability suffered by a player during a match that resulted in the player missing a subsequent match.
Gabbett[85]	Sub-elite (1 sub-elite club over three competitive seasons)	Any pain, disability or injury that occurred as a result of a competition game that caused the player to miss a subsequent game.
Gabbett et al.[96]	Semi-professional (1 club, 153 players over 4 years)	Any pain, disability or injury that occurred as a result of a competition match that caused a player to miss a subsequent match.
Gabbett et al.[98]	Sub-elite (183 players, 2 seasons)	Any pain or disability suffered by a player during a training session that prevented the player from completing that session.
King et al.[153]	Semi-professional (8 teams, 240 players, 1 year)	Any pain or disability suffered by a player during a match that required advice and/or treatment.

Table 4: Injury definitions for amateur participation.

Reference	Level of participation	Injury definition used
Norton et al.[185]	Amateur (24 teams over 1 season)	That which occurred during a match or training, for which medical attention was sought, or the player was unable to attend or take part in training or a match
Pringle et al.[206]	Amateur (1730 players age 6 – 15 yrs old over 1 season)	A minor injury was defined as one where the player was still in discomfort immediately after the game, but was able to play the following week. A moderate injury was defined as one that prevented the player from participating in the following week's game.
Raftery et al.[213]	Amateur (253 junior teams over 1 year)	Any incident which required medical or paramedical review, missed participation at one training session or non-participation in one game
Gabbett[69]	Amateur (9 teams over 3 seasons)	That which was subsequently assessed by the head trainer during or immediately after the match.
Gabbett[73]	Amateur (168 players, 3 rugby league sevens tournaments)	Any pain or disability suffered by a player that was subsequently assessed by the head trainer during or immediately after a rugby league seven's match.
King et al[154]	Rugby league 7's (semi-professional and amateur)	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King[148]	Junior (3 teams in U16 and 1 team in U18 competition)	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King et al.[152]	Amateur (1 team 50 players, 1 year)	Any physical or medical condition that occurred during participation in a rugby league match that required medical treatment or resulted in missed match participation.
King et al.[150]	Amateur women's tournament (5 teams over 3 days)	Any pain or disability suffered by a player during a match that required advice and/or treatment.
King et al.[151]	Amateur training (1 team, 50 players, 1 year)	Any physical or medical condition that occurred during participation in rugby league training activities that required medical treatment or resulted in missed training participation.
Gabbett[92]	Junior rugby league (80 players over four competitive seasons)	Any pain or disability suffered by a player during a match that resulted in the player missing a subsequent match

Definition of injury severity

Assessment of sports injury severity is another aspect that has also not reached consensus in the literature. A recommendation put forward for classification of injury severity has been to relate the injury severity to the amount of missed match or participation time as a result of the injury.[144] Although this has been used in the identification of injury severity, the time difference has varied. For example, a minor injury has been classified as a loss of participation in sporting activities between one to seven days,[144] yet another time loss determination for minor injuries has been up to 28 days.[107]

As can be seen in Table 5, the most commonly used definitions for injury severity in rugby league studies have been:

- Transient (no games or training lost);
- Minor (one game or training week missed);
- Moderate (two to four games or training weeks missed); and
- Major (five or more games or training weeks lost).

In a recent endeavour to standardise the definitions for injury severity,[155] some authors did not agree with the inclusion of transient injuries.[133, 194] Although time loss is identified as the gold standard in reporting rugby league injuries, transient injuries do create an impact on the financial resources of teams and participation of players.[134, 161] Previous studies on injury epidemiology have identified that non-time-loss injury incidence can often account for between 72–95% of the total injuries that occur.[205] These injuries, despite not directly affecting the players participation in matches are important as they have a direct and indirect economic impact[134] through areas such as lost employment and associated rehabilitation costs.

The definition of injury severity:

"Transient (no matches/trainings missed), Minor (1 missed match/training week), Moderate (2 to 4 missed matches/training weeks), or Major (5 or more missed matches/training weeks).[155]"

was eventually agreed upon by the majority of the authors.[155] For the purpose of studies in rugby league, a transient injury is defined as *"any injury that causes a player to seek medical or first aid treatment during or after a rugby league activity but does not lead to loss of further participation or non-selection for matches".*[155] These include injuries that are ongoing but not of sufficient severity to prevent the player from participating in match activities or being selected for match participation. This definition will be utilised for the duration of the research being undertaken.

Table 5: Injury severity classifications.

Author	Non-missed participation	Minor	Moderate	Major	Other
King et al.[151, 153, 154]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	5+ games/training weeks missed	-
Fuller et al.[68] (Rugby Union)	Slight (0 to 1 days) Minimal (2 to 3 days)	4 to 7 days	8 to 28 days	> 28 days	Career ending; non-fatal catastrophic
Hodgson-Phillips et al.[134]	Transient (0 games missed)	1 game missed	2 to 4 games missed	5+ games weeks missed	
Fuller et al [67] (Soccer)	Slight (0 days) Minimal (1-3 days)	4 to 7 days	8 to 28 days	> 28 days	Career ending
King[148]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	5+ games/training weeks missed	-
Gabbett[69, 73, 76-78, 92]	Transient (0 games/training missed)	1 game/training week missed	2 to 4 games/training weeks missed	5+ games/training weeks missed	-
Junge et al.[144]	-	Less than 1 week	1 to 4 weeks	More than 4 weeks	-
Stevenson et al.[232]	-	Self care by participant	Health care professional	Assessed at a hospital	-
Hodson-Phillips et al.[137]	Transient (0 games missed)	1 game missed	2 to 4 games missed	5+ games weeks missed	-
Garraway et al.[107]	-	Up to 28 days	29 – 84 days	More than 84 days	-
Sandelin et al.[219]	-	Less than 1 week	1 to 4 weeks	More than 4 weeks	-
Gibbs[114]	Transient (0 games missed)	1 game missed	2 to 4 games missed	5+ games weeks missed	-

Definition of injury rate

Another problem with previous studies on rugby league injuries is the reporting of the injury rate.[29] Studies have utilised various reporting definitions such as: (a) per 1000 player (game, match) hours; (b) per 1000 hours; (c) per 1000 match or training hours; or (d) per 1000 exposure hours.[29] Comparison between these definitions is sometimes difficult as it is often not clear whether the injury rate comprises match and/or training time (see Tables 6–8). More recently studies have utilised per 1000 training or match hours enabling easier comparison between studies.

The use of a time-loss definition directs attention to those injuries that are most likely to have direct consequences on participants, their team and the clubs performance.[236] The use of this definition understates the effects that non-time-loss injuries have on the health care system (see Tables 6–8).[134]

The time-loss definition also contains certain inaccuracies. An amateur player who trains only twice a week has a greater chance of recovering from an injury before the next training session than a sub-elite/elite level player who trains daily.[144] As well, an injured player may participate in a training session but the participation level may be handicapped by the injury or they may be undergoing a modified training session.[144] The definition of injury rate to be used in this research will be:

Number of injuries per 1000 training or match hours.

Definition of injury exposure and injury rate for rugby league injury

There is no set format for data collection for sports participation.[75, 123-126] The reporting of injury incidence in sports is becoming more standardized thus enabling comparison of results across sporting codes.[222] Studies involving all levels of rugby league participation[78, 87] report the injuries in rates. These rates consist of a denominator (number of athletes, games, appearances) and a numerator (exposure measure)[35, 135] and are expressed as injury rates per thousand playing hours (IR per 1000 playing hours) allowing comparison between sports and different environments (e.g., training, appearances and competition). Rates are calculated to show the injury risk exposure hours, which then can be used to identify the number of injuries that occurred for every thousand hours of participation.

To calculate the injury risk exposure hours for a rugby league team, the number of players (NP) on the field at any time (NP = 13) is multiplied by the game duration (GD) in hours. The GD per match is 80 minutes or 1.33 hours (or less at different participation levels). The result is 17.29 player exposure hours (PEH) per team per game (13NP x 1.33GD = 17.29PEH). By player exposure hours per team per game by the number of games (NG) undertaken (e.g., 23 per season) one arrives at 397.67 game injury risk exposure hours (GIERH) for the team (13NP x 1.33GD x 23NG = 397.67GIERH). [35, 78, 135, 136]

The total number of injuries recorded are divided by the GIERH and then multiplied by 1000 giving an injury rate per 1000 game playing hours. [35, 78, 135, 136] The formula for each team is:

$$(\mathrm{NP} \times \mathrm{GD} \times \mathrm{NG}) = \mathrm{GIERH}$$

NP = Number of players; GD = Game duration in hours; NG = Number of games; GIERH = Game injury exposure risk hours.

The formula for the duration of the competition is:

$$\mathrm{GIERH} \times 1000 = \mathrm{IERH}$$

GIERH = Game injury exposure risk hours; NT = Number of teams; IERH = Injury exposure risk hours.

Once IERH is calculated and the injury number identified, all the injury rates are adjusted to obtain the injury rate per 1000 player hours. This is completed by utilizing the following formula: [69, 72, 73, 76-80, 135]

$$\text{IR/KPH} = \left\{ \frac{\text{TNI}}{\text{IERH}} \right\} \text{x } 1000$$

IR/KPH = Injury rate per 1000 player hours; TNI = Total number injuries; IERH = Injury exposure risk hours.

Table 6: Injury rate expressed as total and missed match/trainings for professional participation.

Reference	Level of Participation	Total Injury Rate	Missed Match/Training Injury Rate
Seward et al.[224]	Professional (8 teams, 3 grades, 1 year)	139 per 1000 player hours	44 per 1000 player hours
Gibbs[114]	Professional (1 club, 3 grades over 3 years)	-	44.9 per 1000 player game hours
Estell et al.[58]	Professional (2 grades) and elite junior (4 teams) over 1 season	242.8 per 1000 player game hours	34.4 per 1000 player game hours
Stephenson et al.[230]	Professional (1 club, 2 grades over 4 seasons)	114.3 per 1000 hours of match play	-
Hodgson-Phillips et al.[137]	Professional (1 team over 4 seasons)	346 per 1000 player hours	38.7 per 1000 player hours
Gissane et al.[118]	Professional (pooled data from 4 prospective studies: [114, 116, 224, 230])	-	40.3 per 1000 player game hours
Gissane et al.[119]	Professional (1 club, 9 seasons)	-	45.5 per 1000 player hours
Orchard[193]	Professional (1 club, 2 grades over 6 seasons)	-	39.8 per 1000 player hours
O'Connor[189]	Professional (100 players from 13 clubs)	-	2.4 per 1000 player hours

Table 7: Injury rate expressed as total and missed match/trainings for semi-professional participation.

Reference	Level of Participation	Total Injury Rate	Missed Match/Training Injury Rate
Gabbett[76]	Semi-professional (60 players over 1 season)	26.9 per 1000 training hours	9.0 per 1000 training hours
Gabbett[77]	Semi-Professional (156 players over 2 seasons)	824.7 per 1000 playing hours	67.7 per 1000 playing hours
		45.3 per 1000 training hours	1.0 per 1000 training hours
Gabbett[81]	Sub-elite (220 players, 3 years)	78.4 to 156.7 per 1000 training hours	19.0 to 33.3 per 1000 training hours
Gabbett[80]	Semi-professional (79 players, 1 year)	105.9 per 1000 training hours	2.2 per 1000 training hours
		917.3 per 1000 playing hours	64.8 per 1000 playing hours
Gabbett[84]	Semi-professional (156 players, 2 seasons)	-	68 per 1000 playing hours
Gabbett[85]	Sub-elite (1 sub-elite club over three competitive seasons	-	72.5 per 1000 playing hours unlimited interchange
			51.0 per 1000 playing hours limited interchange
Gabbett et al.[96]	Semi-Professional (1 club, 153 players over 4 years)	-	55.4 per 1000 playing hours
King et al.[153]	Semi-professional (8 teams, 240 players, 1 year)	114.8 per 1000 playing hours	78.2 per 1000 playing hours

Table 8: Injury rate expressed as total and missed match/training for amateur participation.

Reference	Level of Participation	Total Injury Rate	Missed Match/Training Injury Rate
Norton et al.[185]	Amateur (24 teams over 1 season)	25.0 per 1000 hours of play 0.03 per 1000 hours of training	-
Pringle et al.[206]	Amateur (1730 players age 6 – 15 yrs old over 1 season)	24.5 per 1000 player hours	9.5 per 1000 player hours
Raftery et al.[213]	Amateur (253 junior teams over 1 year)	9.9 per 1000 playing hours	-
Gabbett[69]	Amateur (9 teams over 3 seasons)	160.6 per 1000 game hours	-
Gabbett[73]	Amateur (168 players, 3 rugby league sevens tournaments)	283.5 per 1000 playing hours	-
King et al.[154]	Rugby league 7's (semi-professional and amateur)	497.6 per 1000 playing hours	261.9 per 1000 playing hours
King[148]	Junior (3 teams in U16 and 1 team in U18 competition)	217.3 per 1000 playing hours	129.2 per 1000 playing hours
King et al.[152]	Amateur (1 team 50 players, 1 year)	700.8 per 1000 playing hours	193.9 per 1000 playing hours
King et al.[150]	Amateur women's tournament (5 teams over 3 days)	306.8 per 1000 playing hours	176.2 per 1000 playing hours
King et al.[151]	Amateur training (1 team, 50 players, 1 year)	22.4 per 1000 training hours	16.9 per 1000 training hours
Gabbett[92]	Junior rugby league (80 players over four competitive seasons)	-	56.8 per 1000 playing hours

Classification of injury site and type for rugby league injury

Ideally the classification of injuries should not only include type and location of the injury but also differentiate between trauma induced injuries and those that occur from overuse or overexposure to a causative agent.[144] For example, Van Mechelen[243] suggested that an acute type injury is caused by a single event that causes macro-trauma. If the injury is caused as a consequence of exposure to repetitive micro-traumas then it should be classified as an overuse injury.[102-104]

Table 9: The injury sites selected for use in this research are anatomically based.

• Head (incl. scalp and ears)	• Finger (2nd to 5th phalanges)
• Eye	• Thumb (1st phalanges)
• Nose	• Chest/Trunk (incl. abdomen, lungs, heart, liver, spleen, pancreas, small & large intestine)
• Mouth (soft tissue and tongue only)	• Back (incl. thoracic and lumbar spine
• Teeth	• Groin (incl. groin muscles & pelvis)
• Jaw	• Quadriceps (front of the upper leg)
• Neck (cervical spine and trachea)	• Hamstring (back of the upper leg)
• Shoulder (incl. clavicle & shoulder blade)	• Knee
• Upper arm	• Lower leg
• Elbow	• Ankle
• Lower arm	• Foot
• Wrist (distal radius & ulnar & carpal bones)	• Toes
• Hand (the metacarpal bones)	

Literature specific to rugby league has categorized injuries according to both site and type.[69, 72, 73, 75, 78, 79, 81, 87, 115, 123, 136, 213, 235] The injury sites have been grouped anatomically (see Table 9): Head and neck; thorax and abdomen; upper limbs; shoulder; arm; lower limb; thigh and calf; knee; ankle; and other (hand, foot, finger, face, nose, mouth).[69, 72, 73, 75, 78, 123, 213, 235] Injury types have been classified as concussion, fracture/dislocation, laceration, sprain, strain, haematoma, and others.[69, 72, 73, 75, 78, 123, 213, 235]

The injury types are those classified as commonly used in the literature and enable comparison with other published literature on sports injuries in rugby league.[5, 69, 72, 73, 76, 78, 79, 81, 87, 115, 123, 213, 235] For clarification, the following definitions are utilised in this research for each of the injury types:[178]

- **Concussion:** A traumatic injury to the brain as a result of a violent blow, shaking, or spinning resulting in a transient neurological dysfunction.
- **Fracture:** A break in bone or cartilage, usually the result of trauma. Fractures are classified according to their character and location. Stress fractures result from overuse.
- **Dislocation:** Complete dislocation of a joint also termed a luxation. A partial dislocation is a subluxation. Dislocations result from trauma.
- **Laceration:** A cut or any break in the skin integrity caused by trauma.
- **Sprain:** An injury to a ligament that results from overuse or trauma. Sprains occur when there is a stretch or tear in one or more ligaments (slightly elastic bands of tissue that keep the bones in place while permitting movement at a joint).
- **Strain**: An injury to a tendon or muscle resulting from overuse, trauma or overexertion.
- **Haematoma:** An abnormal localized collection of blood in which the blood is usually clotted or partially clotted and is usually situated within an organ or a soft tissue space, such as within a

muscle. A haematoma is caused by a break in the wall of a blood vessel. Haematoma's result from trauma.

- **Bruise:** or "**contusion**" is a traumatic injury of the soft tissues resulting in breakage of local capillaries and leakage of red blood cells. It can be seen as a reddish-purple discoloration that does not blanch when pressed upon.
- **Other:** All other medical conditions not incorporated with any of the definitions previously identified.

Injury rates for rugby league matches versus training

The majority of injuries occur in the match environment (see Table 10). Several studies have documented these injuries with rates increasing as playing level increases.[78] Amateur injury rates have been reported to range from 135 to 701 per 1000 playing hours.[75, 76, 78, 87, 114, 116, 119-121, 152, 230] Injuries to the head and neck accounted for 25% of these injuries.[69, 72, 73, 80, 87] The face (13%), abdomen and thorax (13%), and knees (11%) being slightly less.[69, 78, 87] These were primarily haematomas and sprains.[7, 58, 69, 72, 77, 87, 114, 116-118, 120, 121, 137, 169, 185, 213, 223, 230, 246] Semi-professional participation injury rate has been reported to range from 1158[149, 153] to 825[77, 78] per 1000 playing hours.

Table 10: Match injury rates expressed as total and missed matches in senior rugby league players.

Study	Playing Level	Injury Rate (# per 1000 playing Hours)	
		All Injuries	Missed Matches
Estall et al.[58]	Professional	210.7	38.5
Alexander et al.[6]	Professional	277.8	-
Alexander et al.[7]	Professional	224.7	-
Orchard[193]	Professional	-	39.8
Gibbs[114, 115]	Professional	-	44.9
Gissane et al.[118]	Professional	-	40.3
Gissane et al.[120]	Professional	174.4	-
Gissane et al.[116]	Professional	114.3	34.0
Gissane et al.[121]	Professional	-	50.3
Hodgson Phillips et al.[137]	Professional	346	52.3
Seward et al.[223]	Professional	139	44.0
Stephenson et al.[230]	Professional	114.3	34.0
Walker[246]	Professional	58.4	-
King et al.[153]	Semi-Professional	114.8	78.2
Gabbett[77]	Semi-Professional	824.7	67.7
King et al.[150]	Amateur women's	306.8	176.2
King et al.[152]	Amateur	700.8	193.9
Gabbett[69]	Amateur	160.6	-
Gabbett[72]	Amateur	-	26.8
Alexander[6]	Amateur	277.8	-

Junior rugby league injuries differed in injury site.[87, 213] Although the lower limb was the most frequent injury region reported (knee 14% and ankle 13%)[87, 213] the shoulder has been reported to be the most common injury site.[92] Injuries to the head and neck occurred in 117% of all junior amateur injuries.[87, 213]

Fractures were more common, especially players between ages 6–17.[87, 213] Defensive strategies, levels of participation and anthropometric aspects of players have been attributed to the differences in injury sites.[69, 78]

Junior rugby league injury incidence increased in correlation with the participation level (Table 11).[213] The injury rate ranged from 1[213] to 197[148] per 1000 playing hours depending upon the age of the participants. The greatest increase coincided with changes in players involved in the game and rule changes associated with age grade rugby league.[42, 43]

Only a few studies have reported training injuries in rugby league.[76-78, 80, 87, 120, 137] These have shown training injury rates to be less (12 to 895 per 1000 training hours) than match injuries.[78, 87] There have been no studies undertaken on junior rugby league training injuries.[78] Amateur training injury rates have been reported to be 22 per 1000 training hours[151] while semi-professional / sub-elite training injury rates have been reported to occur between 27 to 89 per 1000 training hours. [76, 77, 87] Professional training injury rates are reported to be less at 12 per 1000 training hours.[137] Some studies indicate a reduction in training injury rates with an alteration in training methods.[80, 81, 87] The majority of training injuries are reported as transient (44 per 1000 training hours).[79]

Table 11: Match injury rates expressed as total and missed matches in junior rugby league players.

Study	Playing Level	Injury Rate (# per 1000 Playing Hours)	
		All Injuries	Missed Matches
Gabbett[92]	Junior U17-19	-	56.8
King[148]	Junior U18	216.1	197.3
King[148]	Junior U16	218.0	98.3
Estell et al.[58]	Elite under 19	405.6	28.0
Estell et al.[58]	Elite under 17	343.2	17.8
Estell et al.[58]	Elite under 15	197.8	11.0
Raftery et al.[213]	Sub elite under 17	-	15.6
Raftery et al.[213]	Sub elite under 16	-	13.5
Raftery et al.[213]	Sub elite under 15	-	17.1
Raftery et al.[213]	Sub elite under 14	-	16.3
Raftery et al.[213]	Sub elite under 13	-	11.4
Raftery et al.[213]	Sub elite under 12	-	13.0
Raftery et al.[213]	Sub elite under 11	-	6.0
Raftery et al.[213]	Sub elite under 10	-	6.2
Raftery et al.[213]	Sub elite under 9	-	6.0
Raftery et al.[213]	Sub elite under 8	-	1.4
Raftery et al.[213]	Sub elite under 7	-	1.7
Raftery et al.[213]	Sub elite under 6	-	3.4

Incidence of severe injuries occurring in matches or training

Severe injuries occurring in matches have been identified as those that cause the player to miss five or more subsequent matches.[64, 69, 72, 76, 78, 79, 81, 87, 96, 118, 123, 137, 213] Injuries have been associated with players' biological maturity, playing intensity and skills.[75, 98, 213] Approximately 16% to 30% of all rugby league injuries are reported as severe resulting in players missing five or more matches, therefore the injury rate is high.[72, 77, 87, 96, 114, 137] This places demands upon other team members and, if the player returns to playing too early, places them at risk of more injuries.[96]

Amateur match severe injuries have been reported to occur at an injury rate of 27 per 1000 playing hours.[72] Recognizing that a rugby league match is 34.6 hours in duration (13NPx1.33GDx2NTx1NG), a severe match injury could occur once in every match. Semi-professional severe match injury rates have been recorded at 687 per 1000 playing hours.[77, 87] Again this means there could be a severe injury in every match played. Professional severe match injury rate is reported to range from 34 to 52 per 1000 playing hours.[58, 87, 114, 118, 120, 137, 223] Again there is also the risk of a severe match injury every game.

Differences in the reporting of match severe injury rates between the different participation levels may be due to the availability of specialized medical staff at the event, or through the club facilities.[77, 87] Amateur teams may not have such a direct access to these services[72, 87] whereas semi-professional teams may have a physiotherapist and/or team physician present when they play.[77, 78] At the professional level of participation, teams have direct full access to specialized rehabilitation services through their club.[72] Another reason for the lower injury rates in professional teams could be the pressure to return to play,[77, 78] especially if a financial reward occurs as a result of their participation.[77]

A further aspect of match severe injuries is the socio-economical impact.[72, 78, 87, 182] Significant long-term job limitations, medical costs and loss of income have been associated with major match injuries.[72, 78, 87, 182] Gabbett[72] (2001, 2005) identified the mean respective costs associated with severe match injuries was $A75 (medical expenses) and $A205 (wages lost) per playing injury. Meir et al.[182] also reported long-term job limitations, loss of income and medical costs associated with professional rugby league related match injuries.

Costs associated with rugby league in New Zealand (non professional participation) have been reported by the Accident Compensation Corporation (ACC).[4] These range from $3.67 Million (2000/1 – new ($1.37M), ongoing ($2.30M)) to $10.54 Million (2007/8 – new ($4.78M), ongoing ($5.75M)).[4] Injury claims and ongoing related costs in relationship to rugby league injuries reached a reported high in the 2006/7 reporting period with an estimated cost of $10.54 Million.[4] There was an increase of total costs over the 2005/6 to 2006/7 period by $0.32M. This was as a result of 92 more new claims ($0.78M) and 7 more ongoing claims ($0.24M) than the previous reporting year.[4] The increase in costs may be reflective of the change in policy by the governing body, the New Zealand Rugby League, in the requirement of qualified trainers with each team being removed.

Severe injuries occurring in training are uncommon.[78] Amateur training severe injury rates were reported to be 16.9 injuries per 1000 training hours while semi-professional training recorded these as 1 injury per 1000 training hours over two years.[76, 77, 87] Professional training is similar with 1.4 injuries per 1000 training hours being reported.[137] There are no recorded training severe injuries in junior or amateur rugby league studies.[78, 87, 96]

Site, type and cause of rugby league injuries occurring in matches or training

Body sites injured and types of injuries

Early research in rugby league identified that ligament and joint injuries (53.9%) were reported as the major injuries.[114] These occurred mostly to the knee (24.1%).[114] More recently studies have shown a change to anatomical sites being injured at all levels (see Table 12). Commonly reported injury sites are to the head and neck.[6, 7, 69, 73, 77-80, 87, 116, 135, 137, 223, 230] This is thought to be due to changes in the match rules in recent years (i.e., defensive line back to 10 meters, ball stripping in the tackle).[69, 78] Recent published research has identified that the shoulder is now the most commonly reported injury site.[92, 149, 153]

The Australian study on semi-professional participation reported that haematomas (271 per 1000 playing hours) and injuries to the calf and thigh (168 per 1000 playing hours)[77] where the most common type and site of injuries.[77, 87] This is in conflict with another study where strains (28.1 per 1000 playing hours) and injuries to the shoulder (15.7 per 1000 playing hours) were more commonly reported.[149, 152] Injuries to other anatomical sites were higher for the Australian than the New Zealand study (face 115[77, 87] vs. 9[149, 153] per 1000 playing hours; arm and hand 115[77, 87] vs. 13[149, 153] per 1000 playing hours; knee 109[77, 87] vs. 15[149, 153] per 1000 playing hours; and the head and neck 104[77, 87] vs. 14[149, 153] per 1000 playing hours).

Semi-professional training injuries report that the lower limbs incur the majority of injuries in training,[76, 77, 87, 137] with the calf and thigh the most commonly recorded injury site.[76-78, 87, 137] Lower limb strain injuries have been reported to be directly related to an increased need for players to be able to accelerate, decelerate and change direction.[71, 78, 87, 179] The type of training injuries recorded may reflect the emphasis on game specific skills and playing intensity required.[77, 78, 80, 81, 87, 96] The majority of semi-professional injuries occurred in traditional conditioning activities e.g., running, sprints etc.

(90.9 per 1000 training hours).[76] Skill-based conditioning games e.g., ball handling, inter team games etc. incurred less injuries (8.7 per 1000 training hours).[76, 87]

Table 12: Site, type and cause of common rugby league match injuries.

Study	Playing Level	Injury Site	Injury Type	Injury Cause
Alexander et al.[6]	Professional	Head & neck	Haematomas & strains	
Alexander et al.[7]	Professional	Head & neck	Contusions	
Gibbs[114]	Professional	Knee	Ligament & joint	
Gissane et al.[118]	Professional	Lower limb		
Gissane et al.[120]	Professional	Head & neck	Haematomas & strains	Being tackled
Gissane et al.[116]	Professional	Head & neck	Haematomas & strains	Being tackled
Gissane et al.[121]	Professional	Head, neck, knee & shoulder	Joint sprains	Being tackled
Hodgson-Phillips et al.[137]	Professional	Knee	Haematomas & strains	
Seward et al.[223]	Professional	Head & neck	Lacerations & contusions	
Stephenson et al.[230]	Professional	Head & neck	Haematomas & strains	Being tackled
King et al.[153]	Semi-Professional	Shoulder	Haematomas & strains	Being tackled
Gabbett[77]	Semi-professional	Thigh & calf	Haematomas & strains	Being tackled
King et al.[152]	Amateur	Thigh & lower leg	Haematomas & strains	Being tackled
King et al.[150]	Amateur women	Knee & lower leg	Haematomas & strains	Physical collisions
Gabbett[69]	Amateur	Head & neck	Haematomas & strains	
Gabbett[72]	Amateur	Arm & hand	Joint sprains	While tackling
Gabbett[92]	Junior	Shoulder	Sprains	Being tackled
King[148]	Junior	Knee & shoulder	Sprains & strains	Being tackled
Raftery et al.[213]	Junior	Knee	Fractures	Being tackled

The most common injury type for semi-professional participants are muscular strains (137 per 1000 training hours).[76, 77] Other injury causes were overuse (20 per 1000 training hours), fall or stumble (14 per 1000 training hours) and collision with another player (14 per 1000 training hours).[80] Gissane et al. (1993) reported similar findings for professional rugby league players.[87] There has been no research published on training injuries in the National Rugby League (Australia and New Zealand) to enable comparison.

Professional injuries are similar to semi-professional injuries.[78, 87, 114, 115]The most frequent injures (38 per 1000 playing hours) occurred to the head and neck.[230] Other anatomical areas (thigh and calf 20 per 1000 playing hours; knee 12 per 1000 playing hours; thorax and abdomen 10 per 1000 playing hours) occurred less frequently.[78, 114, 115, 230] Muscular injuries were the most frequent injury types (34 per 1000 playing hours).[230] Joint sprains (27 per 1000 playing hours),[230] lacerations (20 per 1000 playing hours)[223, 230] and muscle strains (18 per 1000 playing hours)[230] occurred less frequently.

Cause of injury

Studies have identified that the tackle is the major cause of injuries in rugby league.[72, 77, 87, 96, 116, 120, 121, 123, 213, 230, 246] Between 46–90% of all injuries that occur have been tackle related.[72, 77, 87, 116, 120, 121, 123, 213, 230, 246] Indeed all concussions recorded occur from the tackle.[78, 87] This results from each player being involved in an average of 41 physical collisions per match.[116, 117, 120, 122, 123]

Amateur research also identifies the tackle as the most frequent cause of injuries.[69, 72, 73, 152] Injury rates are reported to be as high as 538 per 1000 playing hours from the tackle.[152] Injuries were more prominent to the ball carrier (405 per 1000 playing hours) than the ball carrier (133 per 1000 playing hours).[152] Junior rugby league also reports a lower injury rate but a similar prominence to amateur rugby league participation.[92, 213]

Research into semi-professional rugby league has also demonstrated that injuries most frequently occurred during the tackle (95[149, 153] to 382[77, 87] per 1000 playing hours). The ball carrier sustained more injuries than the tackler (27%[77, 87] to 44%[149, 153] vs. 20%[77, 87] – 39%[149, 153]). This is a reverse of the trend seen in amateur,[77] and professional rugby league[116, 230] with the ball carrier sustaining more injuries (46 per 1000 playing hours) than the tackler (21 per 1000 playing hours).[116, 230]

Professional tackle injuries have also been shown to increase when the competition format is changed.[119, 137] The rate of tackled player injuries increased from 16 to 30 per 1000 playing hours.[119, 137] The tackling player injuries also increased from 6 to 14 per 1000 playing hours. [119, 137]

Type of player injured during matches and training - Forwards versus backs

Initially research undertaken on rugby league injuries identified that there was no differences between forwards and back injury rates during matches.[114, 116] However, more recent research identified forwards have a higher injury rate than backs.[6, 78, 87, 96, 164, 180, 182, 230] This possibly reflects their greater involvement in physical collisions.[6, 87, 96, 164, 180, 182, 230] Forwards recorded between 55 to 139 per 1000 playing hours tackle related injuries.[116, 117, 121, 230] Backs have a slightly less tackle related injury rate (29 to 93 per 1000 playing hours).[116, 117, 230]

Injury rates have also been studied in defensive and attacking roles in a professional competition.[117] In attack, the injury rates of forwards are higher than backs (16 per 1000 playing hours vs. 13 per 1000 playing hours).[117] This increases when in a defensive role (forwards 39 per 1000 playing hours vs. backs 16 per 1000 playing hours).[117] With seasonal changes positional injury rates increased in both forwards (winter 35 per 1000 playing hours vs. Summer 68 per 1000 playing hours) and backs (winter 26 per 1000 playing hours vs. Summer 54 per 1000 playing hours).[87, 119]

Participation in other levels of rugby league (semi-professional and amateur) can lead to higher injury rate in forwards than backs.[69, 72, 73, 77, 78, 87] Forwards also have higher rates of head, neck, face and knee injuries than backs in all competition levels.[69, 78] Backs have a higher injury rate in the ankles and 'other' categories than forwards.[69, 78]

Semi-professional studies have identified that forwards have a higher incidence of training injuries compared to backs. [77, 78, 87] During trainings the forwards injury rate was 53 per 1000 training hours compared with 38 per 1000 training hours for backs. [77, 78, 87] Forwards also had a higher injury rate to the head and neck, shoulder, thigh and calf, ankle and foot when compared to backs.[77, 87] During the early season period the forward injury rate was 70 per 1000 training hours while backs recorded an injury rate of 48 per 1000 training hours.[77, 87] This decreased for all players by late season with forwards recording 35 injuries per 1000 training hours while the backs recorded 28 injuries per 1000 training hours.[77, 87] The most common training injury type was muscular strains and overuse injury.[77, 87] Forwards recorded more muscular strains (24 per 1000 training hours) than backs (15 per 1000 training hours).[77, 87] They also recorded more overuse injuries (12 per 1000 training hours) than backs (6 per 1000 training hours).[77, 87] There are no position specific training injury research for amateur, junior or professional rugby league.[77, 87]

Time of injury during matches or training

There are limited studies into the timing of injuries during matches.[78] Gabbett[69] reported significantly more injuries in the second (71%) than the first half (29%) in amateur competition.[69, 87] This was reversed in semi-professional[77, 78, 87] with more injuries occurred in the first than the second half of matches (1,014 per 1000 playing hours, 62% vs. 636 per 1000 playing hours, 39%).[78, 87] The injuries are more often sustained in the later part of the season and second half of matches.[69]

Professional competition is reportedly similar to semi-professional competition in most[87, 223] but not all[185] studies for first half injuries (57%). There have been no junior rugby league studies in injury occurrence in relation to time of injury.[78, 87]

The only study on training injury rates has been on semi-professional rugby league.[77, 87] Teams often integrate skill and conditioning sessions in the later stages of the training session to simulate game related conditions promoting skill development under fatigued conditions.[78, 79]The timing of the injury occurrence has been reported to be in the later stages of the training session,[77, 78, 80, 87] a finding that may be related to fatigue.[78, 79, 87]

Seasonal variations for injury

Match injuries

The rugby league season traditionally runs from late summer through to early spring.[119, 121, 137] In the Southern Hemisphere this is from April to September.[72] The northern hemisphere competition was from August to April.[116, 119, 137] Research in Australia[58, 114, 223] reported a higher injury rate than in England.[120, 121, 230] This was due to harder surfaces and higher temperatures.[119, 230] The northern hemisphere competition changed in 1996 requiring players to have a shortened winter season before a compressed summer season.[119, 121, 137] This exposed players to higher temperatures and harder grounds in conditions similar to those experienced in the southern hemisphere.[119, 121, 137] The injury rate[119, 121, 137] doubled from 367 (winter) to 620 per 1000 playing hours (summer).[137] The type of injures remained the same but the risk to the tackler increased twofold[119, 137].

Traditional winter injury rates have been reported to fluctuate throughout the season.[69, 75, 76, 78, 87, 114, 116, 119-121, 230] Amateur match injuries occurred more in the latter half of the season.[69, 78, 87] The injury rate at the start of the season was 134 per 1000 playing hours (March).[69] This declined in April but progressively increased from May to September culminating at 196 per 1000 playing hours.[69] The increasing injury rate has been attributed to fatigue and accumulative microtrauma.[69, 78, 87] Other influences reportedly are environment changes and ground hardness near the end of the season.[78, 87, 192]

Semi-professional studies have identified a similar trend in injury rates.[77] The injury rate increased from 561 to 1339 per 1000 playing hours.[77] This trend was consistent for all playing positions.[77] The increasing injury rate was attributed to playing intensity as the final series approached,[77, 87] a concept supported by Gabbett[80] who found a significant correlation (r=0.74) between match injury rates and match intensity.[80, 87]

Professional studies have also identified similar trends.[78, 137] The injury rate increased as the season progressed.[7, 137] The injury severity also increased when the northern hemisphere season changed. Some studies have identified a slight variation with more injuries at the beginning of the season,[120, 223] with a decrease midseason before rising towards the final series.[120]

Training injuries

During the training pre-season period (December to April) the injury rate was 157 per 1000 training hours (2001).[81, 87] This reduced to 78 per 1000 training hours in 2003 by changing training methods and routines.[81, 87] The training methods changed were from traditional conditioning activities to game specific skill-based conditioning games.[81, 87]

The injury rates were noted to increase from December to March.[81, 87] The highest injury rate was recorded yearly in February with an average of 142 per 1000 training hours.[81, 87] This decreased in March, prior to the season starting and was identified to be the result of altering the training intensity.[81, 87]

Training injury rates through the season (April to September) have been recorded to be highest early season.[77, 78, 87, 165] This has been recorded as 116 per 1000 training hours[77, 78, 87] which is reportedly 2.6 times higher than the season average rate of 45 per 1000 training hours.[77, 78, 87] Training injury rate decreased as the training intensity decreased through the season.[77, 87] The high injury rate at the beginning of the season has been found to be significantly correlated (r=0.86)[78] to the increased training loads.[77, 78, 87] This suggests that more injuries occur when players train harder.[77, 78, 80, 87]

Professional training injuries have been recorded at 12 per 1000 training hours.[137] Gissane et al.[120] reported a similar injury rate for training injuries over a season (1990–91) for a professional team in England. Studies on professional rugby league[120, 137] participation have not identified training injuries in detail.

Part 3: Anthropometric and physiological characteristics

Several studies looking at the anthropometric and physiological aspects of rugby league participants have been published (see Table 13). Changes in the rules of rugby league have resulted in changes in the physiological demands placed on participants.[85, 198] These changes include the move from a five metre (5-m) to a 10-m defensive line following each tackle[181] and the introduction of the limited interchange replacement rule[85, 198] have required different training techniques and increased aerobic, strength, endurance and anaerobic requirements.[181]

Table 13: Anthropometric and/or physiological assessments of rugby league participants by country.

Playing population	Pre-season	Season duration
Male Professional	• England[10] • Australia[11-15, 18, 95, 186]	• None
Female teams	• Australia[91]	• None
Male semi-professional teams	• England[10] • Australia[28, 44, 74, 95, 103]	• None
	• New Zealand[149]	• None
Male sub-elite teams	• Australia[11, 12, 14, 70, 75, 88-90, 101]	• None
Male Amateur teams	• Australia[70]	• Australia[82]
Masters teams	• None	• None
School-boy teams	• Australia[14]	• None
School-girl teams	• None	• None
Junior elite	• Australia[75, 88, 98, 102]	• None
Junior	• Australia[14, 83]	• Australia[86]
Reviews	• Australia[27, 87, 104]	• None

Body composition

Meir et al.[183] has shown that excess body fat and body mass have a detrimental effect on participant sporting performance. This can occur in areas such as aerobic capacity, thermoregulation and power to body mass ration.[183] When comparing rugby league to other team sports, such as Australian footballers soccer and rugby league participants have been shown to have a higher body mass and percentage of body fat.[188]

Although amateur level participants have been reported to have a percentage of body fat that is 31% higher than professional level participants,[70, 87, 104] the percentage of body fat between forwards and backs it is seen to be similar at all levels of participation (see Figure 1).[28, 70, 83] This was similar for mean body mass measurements. Although amateur participants body mass have varied,[70, 75, 83, 87, 104] when comparing the different participation levels it has been shown that there are no significant differences observed in the mean body mass between forwards and backs (see Figure 2).[70, 74, 91, 98, 188]

Forwards have been reported to have a higher body mass than backs in most,[164, 230] but not all[180] published studies. It was also identified that body mass was the only physical characteristic that predicted selection into a first grade team[87, 104] or to be a forward or back.[87, 104] The requirement for forwards to spend more time involved in physical collisions[14, 15, 24] and tackles[87, 104] than backs may be reflective of the higher body mass and percentage of body fat recorded.[214]

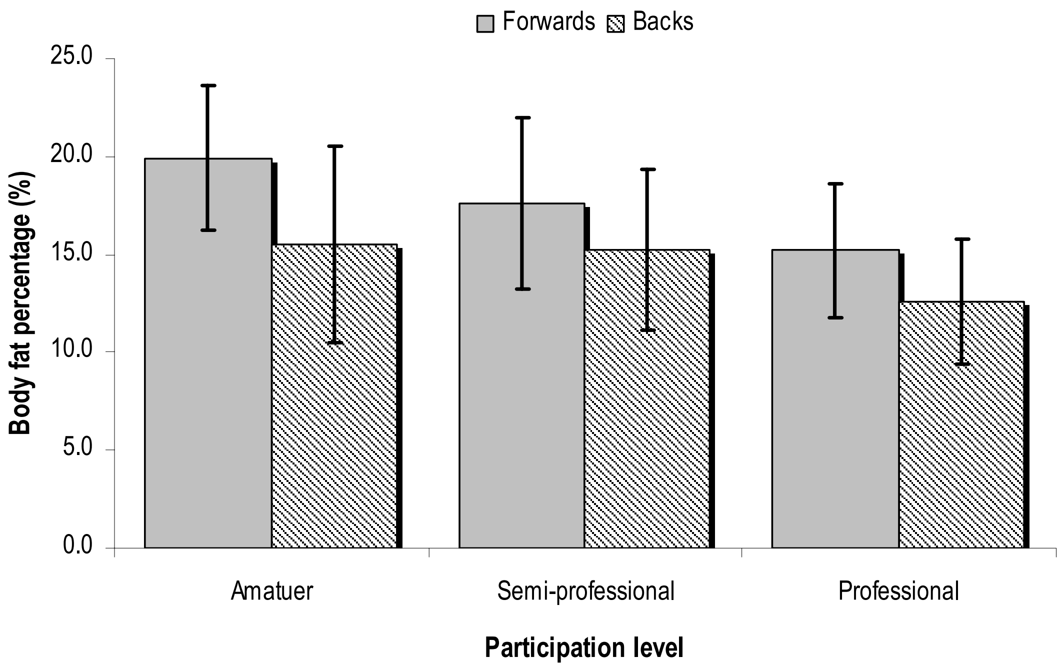

Figure 1: Comparison of body fat percentages (±SD) for amateur, semi-professional and professional levels of participation.

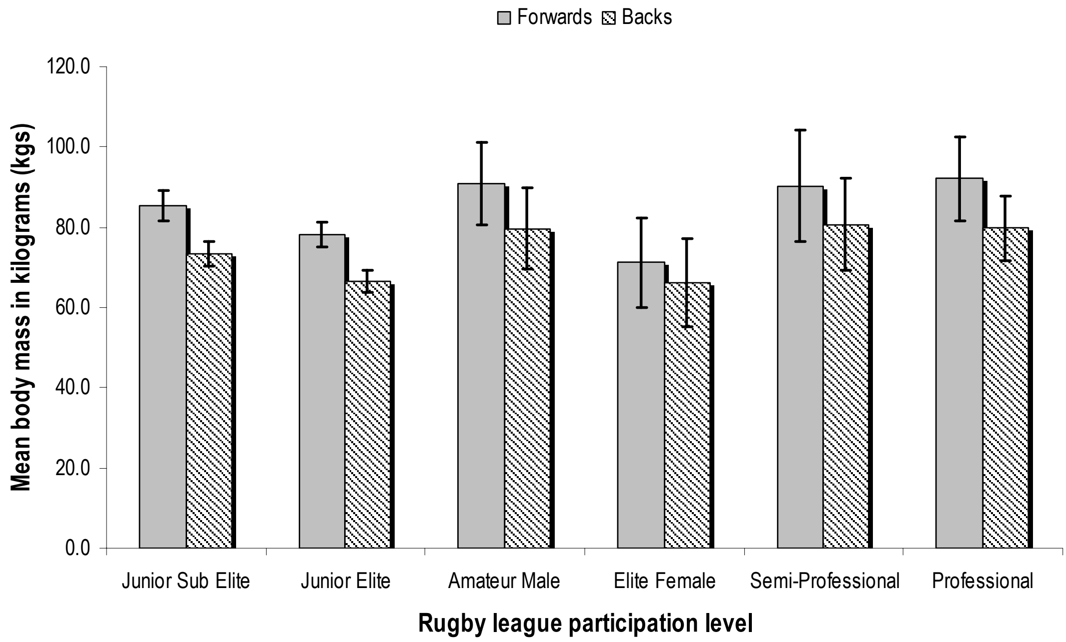

Figure 2: Comparison of body mass (±SD) amongst different participation levels in rugby league.

A higher body mass may also assist forwards in two ways: (1) the development of greater impact forces associated with match participation;[75] and (2) may act as a means of impact injuries.[98] However, to date no scientific evidence exists to refute or support this.[91] There have been no studies that have looked at body compartment models for body composition characteristics (i.e., bone mass, fat mass, muscle mass and residual mass), nor proportional anthropometric characteristics using the Phantom stratagem and predication of performance.

Anaerobic endurance

As previously described, rugby league is a sport characterised by intermitted efforts of low to high-intensity activity that uses both the aerobic and anaerobic pathways.[27] It is an important criterion for performance in rugby league[10] and is utilised during short-term explosive efforts such as tackling, sprinting and scrummaging.[27, 181] The demands of completing repetitive 10 meter movements up and back, and tackling the opposition participant to either a standstill or wrestling them to the ground, for six or more tackles in rugby league can place a high demand on the participants anaerobic glycolytic system.[138] Despite the requirements of anaerobic capacity in rugby league, anaerobic endurance is not currently systematically assessed in rugby league participants.[138]

Video analysis has identified that the mean ±SD tackles made per defensive set in a match ranged from 3.7 ±1.5 - 4.0 ±1.2 for professional participants and 3.3 ±1.8 - 3.4±1.5 for semi-professional participants.[138] The mean time spent in a defensive set range from approximately 37.0 to 47.0 seconds (Professional 38.1 ±15.3 s to 46.9 ±13.6 s; Semi-professional 37.1 ±15.1 s to 38.3 ±18.5 s).[138]

Based on this, the triple-120 meter shuttle test (T120S) was designed to test the anaerobic system by mimicking the action of a defensive set.[138] The test requires the participant complete a set of six 10 meter sprints combined with three simulated tackles. This test enables assessment of anaerobic endurance simulating tackles without the actual potential for injuries associated with tackling. The results of the T120S were similar to actual match data ranging from 42.5 ±1.7 s to 49.5 ±2.1 s.[138]

Maximal aerobic power

Maximal aerobic power (VO_2max) has been reported to be reflective of the level of "cardiorespiratory" or "endurance fitness" of the participant.[238, 239] The testing of participants VO_2max has been utilised to enable identification of participants "cardiorespiratory" or "endurance fitness" in rugby league and allows for intra-study comparisons. When comparing the different participation levels VO_2max, the endurance fitness levels become obvious. Professional participants train upwards of five to six times a week and may perform multiple trainings sessions per day. Consequently the VO_2max of professional participants is higher than that of other participation levels (see Figure 3).

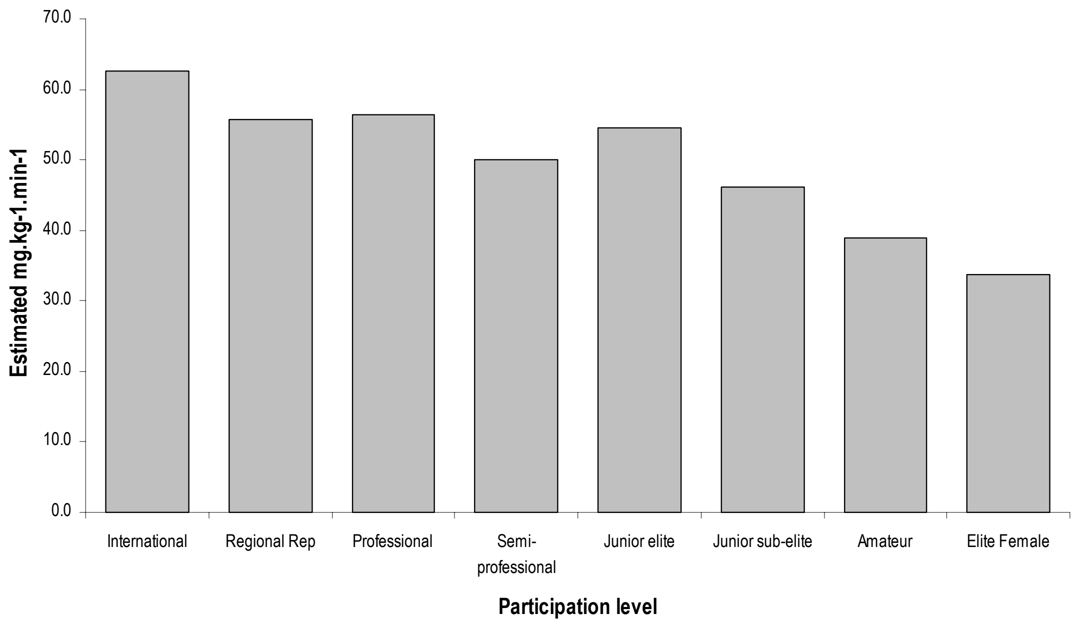

Figure 3: Comparison of estimated maximal aerobic power by participation level.

Amateur participants have been reported to have a poorly developed maximal aerobic power.[187] Reportedly 20 to 42% lower than professional rugby league participants estimated mean VO_2max,[28] amateur participant's aerobic fitness has been attributed to a low playing intensity, infrequent matches of short duration and an inadequate training stimulus.[74] A higher percentage body fat may also contribute to the lower estimated mean VO_2max at this level of participation.[70] When comparing positional VO_2max differences of rugby league participants, backs and forwards are similar suggesting that positional fitness training is similar for all playing positions (see Table 13).[149]

The study on sub-elite under 16 year-old rugby league participants identified that backs had a significantly higher mean VO_2max (49.5 $ml \cdot kg^{-1} \cdot min^{-1}$) than forwards (42.9 $ml \cdot kg^{-1} \cdot min^{-1}$).[75] It was suggested that the volume and intensity of training may differ between forwards and backs in this age group of participants.[75]

Table 13: Maximal aerobic power (VO_2max) comparisons of forwards and backs between different participation levels.

	Forwards		**Backs**	
	VO_2max	±SD	**VO_2max**	±SD
Professional[75]	56.4	-	55.4	-
Semi-professional 1st grade[75]	45.8	4.4	48.0	3.6
Semi-professional 2nd grade[75]	45.6	4.9	44.9	4.2
Semi-professional[83]	50.5	4.8	54.1	4.3
Elite female[91]	32.2	4.4	35.3	3.4
Sub-elite 1st Grade[75]	50.0	2.4	50.1	2.7
Sub-elite 2nd Grade[75]	45.5	2.7	45.0	3.5
Sub-elite U19[75]	43.9	3.6	46.1	3.8
Sub-elite U16[75]	42.9	2.8	49.5	3.1
Sub-elite U15[75]	38.5	3.0	41.4	2.7
Sub-elite U14[75]	40.5	5.0	40.8	3.8
Sub-elite U13[75]	32.1	2.5	36.2	2.4
Amateur[75]	38.1	2.7	40.0	2.2

VO_2max expressed as $ml \cdot kg^{-1} \cdot min^{-1}$

Despite the similarities between forwards and backs at amateur, semi-professional and professional levels of participation, it has been recorded that different positional groups in rugby league have significant different estimated mean VO_2max scores (see Tables 14 and 15).

Table 14: Maximal aerobic power (VO_2max) comparisons between different positional groups in rugby league.

Level	Prop		Hookers/Halves		Backrowers		Outside Backs	
	VO_2max	±SD	VO_2max	±SD	VO_2max	±SD	VO_2max	±SD
Professional[188]	48.6	-	55.2	-	51.1	-	52.8	-
Sub-elite[83]	42.6	±6.5	46.5	±6.4	44.9	±6.5	46.1	±6.3
Semi-Professional[149]	48.3	-	55.4	-	51.4	-	55.1	-
Junior[83]	42.2	-	48.4	-	45.0	-	46.6	-

VO_2max expressed as $ml \cdot kg^{-1} \cdot min^{-1}$

Only a few studies have documented changes in VO_2max of characteristics over a competitive season (see Table 16).[82, 86] These studies identified that the greatest improvements occurred in the early stages of the season but deteriorated at the end of the season.[82, 86] This deterioration has been suggested to occur as a result of decreased training loads, increased match loads and high injury rates.[82, 207] This has been attributed to a high overall playing intensity, increases in injury rates and residual fatigue associated with limited recovery time between matches.[82]

Speed and sprint ability

The requirement to move quickly to reposition themselves in attack and defence is essential for rugby league participants.[98] Professional rugby league studies have identified that forwards rarely sprint further than 10-m in and all rugby league participants rarely sprint distances greater than 40-m in a single bout of intense activity.[70] Although there are no significant differences between forwards and backs for 10-m speed, forwards were consistently slower over 40-m than backs.[74] This was similar for junior sub-elite participants where no significant differences were reported for 10-, 20- and 40-m sprint speeds[74, 75, 98] but, like other studies, forwards were reportedly consistently slower than backs.[98]

Table 15: Maximal aerobic power (VO_2max) comparisons between different playing positions in rugby league.

Level	Prop		Hooker		Second Row		Lock		Half-Back		Five-eighth		Centre		Wing		Fullback	
	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range	VO_2max	Range
Semi-Professional[149]	48.33	-	48.94	-	55.42	-	51.44	-	55.42	-	51.73	-	55.14	-	54.57	-	55.42	-
Sub-elite[88]	42.6	±6.5	46.7	±7.0	44.4	±6.9	46.1	±5.4	47.3	±6.2	45.5	±5.3	46.6	(±6.2)	45.2	±6.7	47.0	±5.8
Junior[83]	42.2	-	46.9	-	45.1	-	44.6	-	50.5	-	48.3	-	47.1	-	45.7	-	47.8	-

VO_{2MAX} expressed as $ml{\cdot}kg^{-1}{\cdot}min^{-1}$

Table 16: Maximal aerobic power (VO_2max) changes over a competitive season for amateur and junior participants.

	Amateur[82]		Junior[86]	
	Training		Training	
	VO_2max	95% CI	VO_2max	95% CI
Off season	42.0	(38.8 to 45.1)	43.7	(39.9 to 47.5)
Pre season	48.5	(46.1 to 50.9)	50.6	(48.5 to 52.8)
Mid season	51.3	(49.6 to 52.9)	53.5	(51.7 to 55.3)
End season	49.6	(47.5 to 51.7)	52.1	(50.5 to 53.8)

VO_2max expressed as $ml{\cdot}kg^{-1}{\cdot}min^{-1}$

Amateur rugby league participants[91] are predictably slower in sprint speeds than semi-professional[37] and professional[188] levels of participation. Female participants[88] recorded even lower sprint speeds. Backs were predictably faster than forwards at all participation levels (see Table 17).

Table 17: Sprint speed of forwards and backs by participation level.

Level	Position	10-M	95% CI	20-M	95% CI	30-M	95% CI	40-M	95% CI
Professional[183]	Forward	-	-	-	-	-	-	5.27	-
	Back	-	-	-	-	-	-	5.08	-
Professional[179]	Forward	-	-	-	-	-	-	5.04	-
	Back	-	-	-	-	-	-	4.88	-
Professional[37]	Forward	1.88	-	3.18	-	4.39	-	5.57	-
	Back	1.79	-	3.07	-	4.14	-	5.28	-
Semi-Professional 1st Grade[74]	Forward	2.19	-	3.56	-	4.94	-	6.12	-
	Back	2.09	-	3.38	-	4.68	-	5.86	-
Semi-Professional 2nd Grade[74]	Forward	2.20	-	3.56	-	4.80	-	6.12	-
	Back	2.18	-	3.52	-	4.80	-	6.02	-
Elite[98]	Forward	1.88	(1.85 to 1.91)	-	-	-	-	5.64	(5.53 to 5.75)
	Back	1.82	(1.79 to 1.85)	-	-	-	-	5.45	(5.38 to 5.52)
Sub-Elite[98]	Forward	2.19	(2.14 to -2.24)	-	-	-	-	6.25	(6.10 to 6.40)
	Back	2.12	(2.06 to 2.18)	-	-	-	-	5.98	(5.88 to 6.08)
Sub-Elite 1st Grade[75]	Forward	2.05	(1.97 to 2.13)	3.38	(3.28 to 3.48)	-	-	5.86	(5.76 to 5.96)
	Back	1.98	(1.93 to 2.03)	3.28	(3.21 to 3.35)	-	-	5.69	(5.58 to 5.80)
Sub-Elite 2nd Grade[75]	Forward	2.14	(2.09 to 2.19)	3.50	(3.43 to 3.57)	-	-	6.09	(5.94 to 6.24)
	Back	2.08	(1.97 to 2.19)	3.34	(3.22 to 3.46)	-	-	5.81	(5.64 to 5.98)
Sub-Elite U19[75]	Forward	2.19	(2.10 to 2.28)	3.57	(3.46 to 3.68)	-	-	6.20	(6.01 to 6.39)
	Back	2.19	(2.09 to 2.29)	3.53	(3.41 to 3.65)	-	-	6.01	(5.85 to 6.17)
Sub-Elite U16[75]	Forward	2.22	(2.15 to 2.29)	3.61	(3.51 to 3.71)	-	-	6.17	(6.00 to 6.34)
	Back	2.17	(2.10 to 2.24)	3.55	(3.46 to 3.64)	-	-	6.00	(5.87 to 6.13)
Sub-Elite U15[75]	Forward	2.25	(2.20 to 2.30)	3.72	(3.61 to 3.83)	-	-	6.58	(6.32 to 6.84)
	Back	2.21	(2.13 to 2.29)	3.62	(3.53 to 3.71)	-	-	6.26	(6.14 to 6.38)
Sub-Elite U14[75]	Forward	2.44	(2.34 to 2.54)	3.99	(3.79 to 4.19)	-	-	7.00	(6.40 to 7.60)
	Back	2.24	(2.15 to 2.33)	3.70	(3.51 to 3.89)	-	-	6.47	(6.08 to 6.86)
Sub-Elite U13[75]	Forward	2.60	(2.53 to 2.67)	4.24	(4.14 to 4.34)	-	-	7.50	(7.29 to 7.71)
	Back	2.46	(2.38 to 2.54)	4.04	(3.92 to 4.16)	-	-	7.11	(6.87 to 7.35)
Elite Females[91]	Forward	2.04	-	3.60	-	-	-	6.59	-
	Back	1.96	-	3.44	-	-	-	6.33	-
Amateur[70]	Forward	2.62	(2.57 to 2.67)	-	-	-	-	6.79	(6.69 to 6.89)
	Back	2.53	(2.43 to 2.63)	-	-	-	-	6.45	(6.35 to 6.55)

Data reported as means. CI Confidence Interval

Relatively few studies have investigated the repeated-sprint ability of rugby league participants. This is despite the nature of rugby league where repeat-sprint ability is important. Participants are often required to sprint from the defensive line, make a tackle, chase from marker defence and then recover to enable a repeat of these activities. The repeated sprint ability test is specifically designed to test the athlete's ability to perform in short bursts of high intensity exercise over a series of multiple efforts.[37, 188] A limitation to conducting this test is that repeated sprint efforts in rugby league can vary in distance and recovery duration.[188] Meir et al.'s[37] study on time-motion activities of professional rugby league participants identified that for every four seconds of high-intensity activity, approximately 30–80 seconds of low-intensity followed. Further research is required to provide information on the repeated demand of rugby league at all levels of participation.[188]

Of the two studies[37] published on repeat-sprint ability, one study[37] used a 8 x 40-m repeat sprint test while the other study[37] used an 6 x 40-m repeat sprint test. No significant differences between player positions in professional rugby league participants when the 8 x 40-m sprints test[37] but when compared with the 6 x 40-m sprint test, significant differences were reported amongst the different playing positions.[248] Props were reported to have the highest speed decrement (7%) followed by outside backs (6%), back-rowers (6%).[179] Halves and hookers recorded the lowest speed decrement at 5%.[216] Although forwards recorded a slower total time to complete the repeat-sprint ability test than backs (35.02 vs. 33.65 s) they recorded a lower speed decrement than backs (5.8% vs. 6.4%).[14, 16]

Agility

Described as "a rapid whole body movement with change of velocity or direction in response to a stimulus",[225, 226] agility is an essential component for rugby league participants as they are required to rapidly accelerate, decelerate and change direction.[180] There are several agility tests[103] reported in the literature including the Illinois agility (see Table 18), 'L' agility (see Table 19), 505 test (see Table 20), Modified 505 test, glycolitic agility (see Table 21) and the reactive agility test[103] and other 'novel'[19] tests. This is reported to be a limitation of the current studies as none of the tests assess perceptual components of agility.[103] Inter-study comparisons are difficult to undertake because of the different tests utilised.

Table 18: Illinois agility published results by participation level.

	Forwards		Backs		All Participants	
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**
First Grade[74]	17.2 ±1.0§	-	16.6 ±0.7§	-	16.9 ±0.9§	-
First Grade[75]	17.2¥	(16.6 to 17.8)	17.4¥	(16.7 to 18.1)	-	-
Second Grade[74]	17.2 ±1.2§	-	17.5 ±1.4§	-	17.4 ±1.3§	-
Second Grade[75]	18.1¥	(17.6 to 18.6)	17.7¥	(17.3 to 18.1)	-	-
Under 19[75]	18.3¥	(17.5 to 19.1)	17.9¥	(17.2 to 8.6)	-	-
Under 16[75]	19.4¥	(18.5 to 20.3)	19.1¥	(18.4 to 19.8)	-	-
Under 15[75]	19.5¥	(18.5 to 20.5)	19.5¥	(18.9 to 20.1)	-	-
Under 14[75]	21.1¥	(19.4 to 22.8)	20.3¥	(19.4 to 21.2)	-	-
Under 13[75]	22.0¥	(21.5 to 22.5)	21.5¥	(20.9 to 22.1)	-	-

All data reported in seconds (s). **§** Data reported as mean (±SD). **¥** Data reported as mean (95% CI).

CI = Confidence Interval.

Table 19: 'L' agility test published results by participation level.

	Professional[179]		Sub-Elite[88]		Junior[83]		First Grade[103]		Second Grade[103]	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Total§	-	-	-	-	-	-	6.36	±0.53	6.49	±0.40
Forwards§	5.46	±0.21	6.04[a]	±0.54[a]	5.99[a]	±0.31[a]	-	-	-	-
Backs¥	5.37	±0.22	5.98[a]	±0.52[a]	5.90[a]	±0.12[a]	-	-	-	-
Prop¥	-	-	6.36	±0.48	6.37	(6.21 to 6.52)	-	-	-	-
Hooker¥	-	-	5.83	±0.60	5.86	(5.61 to 6.11)	-	-	-	-
Second Row¥	-	-	6.11	±0.60	6.10	(5.91 to 6.30)	-	-	-	-
Lock¥	-	-	5.84	±0.47	5.64	(5.35 to 5.94)	-	-	-	-
Half-Back¥	-	-	5.93	±0.47	6.01	(5.79 to 6.24)	-	-	-	-
Five-eighth¥	-	-	6.16	±0.64	5.71	(5.34 to 6.08)	-	-	-	-
Centre¥	-	-	5.94	±0.44	5.89	(5.68 to 6.09)	-	-	-	-
Wing¥	-	-	5.96	±0.54	5.98	(5.85 to 6.12)	-	-	-	-
Fullback¥			5.89	±0.50	5.90	(5.72 to 6.08)	-	-	-	-

All data reported in seconds (s) **§** Data reported as mean (±SD). **¥** Data reported as mean (95% CI).

CI = Confidence Interval. a= calculated mean (±SD) of 'L' agility scores.

Table 20:505 agility test published results by participation level.

	Mean	Total SD or 95% CI
Junior Elite[102]	2.30§	±0.13
Junior Sub-Elite[102]	2.38§	±0.16
Elite Under 17[98]	2.36¥	(2.28 to 2.44)
Elite Under 16[98]	2.40¥	(2.35 to 2.45)
Elite Under 15[98]	2.45¥	(2.41 to 2.49)
Sub-Elite Under 17[98]	2.68¥	(2.60 to 2.76)
Sub-Elite Under 16[98]	2.85¥	(2.80 to 2.90)
Sub-Elite Under 15[98]	2.89¥	(2.85 to 2.93)
Sub-Elite Forward[98]	2.77¥	(2.72 to 2.82)
Sub-Elite Backs[98]	2.76¥	(2.61 to 2.91)
Elite Forwards[98]	2.45¥	(2.41 to 2.49)
Elite Backs[98]	2.38¥	(2.34 to 2.42)
First Grade[103]	2.34§	±0.20
Second Grade[103]	2.39§	±0.15

All data reported in seconds (s)

§ Data reported as mean (±SD). **¥** Data reported as mean (95% CI).

CI = Confidence Interval.

More recently other agility tests reported in the literature. A 'novel' test used on professional and semi-professional participants necessitated a 40-m distance to be covered incorporating two 45º and a single 135º turn to be made.[19] It was thought that this would mimic some aspects of movement when participants are defending.[19] The other agility test reported is the Reactive Agility Test (RAT). Initially utilised in netball,[60] the RAT has been compared with change of direction speed and sprint speed[103, 226] and with other agility tests.[103] The study identified superior movement speed (2.48 ±0.17 s vs. 2.60 ±0.16 s), decision times (55.3 ±43.6 ms vs. 78.2 ±40.4 ms) and response accuracy (89% ±14% vs. 84% ±17%) in first grade compared with second grade players.[103] It also demonstrated the practical utility of the RAT for assessment of perceptual components of agility in participants.[103]

Table 21: Glycolitic agility test published results by participation level.

		Mean	±SD or Range
Professional[188]	Backs[a1]	45.3	±3.33
	Halves[a2]	45.89	±3.03
	Backrow[a3]	46.55	±2.73
	Props	46.71	±2.89
	Hookers	46.20	±2.84
Professional[186]	Backs	44.92	(40.20 to 51.90)
	Forwards	46.67	(41.83 to 52.32)
	Under 21	46.01	(40.27 to 51.90)
	Reserve Grade	46.00	(40.20 to 52.32)
	First Grade	45.09	(40.20 to 52.30)
Elite Women[91]	Forwards	53.1	±2.6
	Backs	51.6	±3.7
	Hit Up Forwards	53.5	±2.9
	Adjustables	51.9	±1.7
	Outside Backs	51.2	±5.1

All data reported in seconds (s) **§** Data reported as mean (±SD). **¥** Data reported as mean (range)

a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row.

Muscular strength and power

For rugby league participants to be successful the key characteristic is the capacity to generate high levels of muscular force. Meir et al.[183] identified that rugby league participants needed to have high levels of muscular strength to effectively tackle, lift, pull and push opponents during match activities. Muscular strength and power are also reported to be an essential requirement to provide fast play the ball speed and to enable leg drive to occur in the tackle.[104]

There are several studies that have examined strength characteristics of rugby league participants.[11, 12, 14, 17, 183, 188] Meir[179] reported significant differences between forwards and backs for bench press (119 vs. 113 kgs) and one-repetition maximum (1-RM) squat (188 vs. 168 kgs). O'Connor[188] confirmed these findings by also reporting significantly greater three-repetition maximum (3-RM) squat, power-clean and bench-press in props (149.3 kg, 92.5 kg, 123.4 kg) and back rowers (143.5 kg, 86.8 kg, 112.4 kg) when compared with hookers (130.0 kg, 76.0 kg, 99.7 kg), halves (131.0 kg, 78.8 kg, 100.1 kg) and outside backs (135.6 kg, 81.4 kg, 106.0 kg).

In other studies[11, 14-16, 188] it was reported that professional rugby league participants had a 3-RM squat of 157.9 ±18.8 kgs, a 3-RM bench press of 124.0 ±13.0 kgs and a 3-RM power clean of 102.2 ±13.4 kgs. When compared with college aged,[11] and junior high school aged rugby league,[14] professional rugby league participants reportedly are significantly greater in maximal strength and power. This has been attributed, in part, to the neural adaptations that have occurred with long-term periodised strength and power training that professional participants undertake in their training regime.[98]

Table 22: Vertical jump scores of forwards and backs by participation level.

	Forwards		Backs	
Study	VJ (cms)	95% CI	VJ (cms)	95% CI
Semi-professional 1st Grade[74]	40.7	-	46.7	-
Semi-professional 2nd Grade[74]	43.7	-	40.2	-
Elite[98]	51.1	(48.9 to 53.3)	54.1	(51.5 to 56.7)
Sub-Elite	38.2	(35.2 to 41.2)	40.6	(38.0 to 43.2)
Sub-Elite 1st Grade[75]	48.7	(42.1 to 55.3)	50.9	(47.5 to 54.3)
Sub-Elite 2nd Grade[75]	41.0	(37.8 to 44.2)	42.9	(39.3 to 46.5)
Sub-Elite Under 19[75]	37.9	(33.1 to 42.7)	40.0	(35.1 to 44.9)
Sub-Elite Under 16[75]	38.0	(34.4 to 41.6)	41.2	(37.7 to 44.7)
Sub-Elite Under 15[75]	34.7	(29.2 to 40.2)	37.1	(34.3 to 39.9)
Sub-Elite Under 14[75]	33.1	(26.8 to 39.4)	38.5	(32.7 to 44.3)
Sub-Elite Under 13[75]	28.2	(21.7 to 34.7)	30.8	(38.2 to 33.4)
Elite Females[91]	35.1	-	35.7	-
Amateur[70]	37.1	(33.7 to 40.5)	39.3	(36.1 to 42.5)

Data reported as mean scores. CI = Confidence Interval. VJ = Vertical Jump.

Some studies that have examined strength in rugby league participants have used the vertical jump test to assess leg muscular power.[98] There is a progressive improvement in the muscular power as the participation level increased (see Table 22). Gabbett et al.[102] identified that participants that were selected to start in the first match of the season had a greater mean vertical jump score than the non-starters for both junior elite (52.6 ±7.8 vs. 49.4 ±7.5 cms) and junior sub-elite (46.8 ±7.3 vs. 45.9 ±7.7 cms) participants.

Table 23: Vertical jump scores of rugby league positional by participation level.

Study	Participation level	Positional group	Mean (cms)	(±SD)	(95% CI)
O'Connor[188]	Professional	Backs[a1]	45.30	3.33	-
		Halves[a2]	45.89	3.03	-
		Backrow[a3]	46.55	2.73	-
		Props	47.61	2.89	-
		Hookers	46.20	2.84	-
Gabbett[88]	Sub-Elite	Props	43.4	9.0	-
		Hooker/Halves[b1]	47.7	10.3	-
		Backrowers[b2]	46.0	11.1	-
		Outside backs[b3]	48.3	10.6	-
Gabbett[91]	Elite Female	Hit up forwards[c1]	34.3	8.6	-
		Adjustables[c2]	35.6	5.5	-
		Outside backs[c3]	37.0	7.0	-
Gabbett[83]	Junior	Props	44.0	-	(41.6 to 46.4)
		Hooker/Halves[b1]	49.0	-	(46.2 to 51.7)
		Backrowers[b2]	48.2	-	(45.1 to 51.3)
		Outside backs[b3]	47.1	-	(45.1 to 49.1)

a1= Fullback, wing, centre; a2= five eight/stand-off, half-back; a3= lock, second row;

b1= Hooker, halfback, five-eight/stand-off; b2= second row, lock; b3= centre, wing, fullback;

c1= second row, prop; c2= hooker, half-back, five-eight/stand-off, lock; c3= centre, wing, fullback.

Comparison of positional groups muscular strength by use of the vertical jump is limited as different authors have used either different positional group combinations[70, 74, 83, 88, 102] with either standard deviations[88] or 95% confidence intervals[83] (see Table 23) player positions and either standard deviations[88] or 95% confidence intervals[83] (see Table 24) or a mean score for all participants[70, 74, 102] (see Table 25). These studies have shown that the different participation levels have varying results with no one playing group or position recording greater vertical jump scores throughout all participation levels.

Table 24: Vertical jump height scores of rugby league specific positions by participation level.

	Sub-Elite[88]		Junior[83]	
Playing position	**cm**	**±SD**	**cm**	**(95% CI)**
Prop	43.4	9.0	44.0	(41.6 to 46.4)
Hooker	50.9	10.5	47.9	(44.3 to 52.0)
Second Row	45.7	10.5	49.0	(45.5 to 52.6)
Lock	46.6	12.4	45.2	(38.6 to 51.8)
Halfback	48.4	9.0	50.4	(45.8 to 54.0)
Stand Off	41.0	7.7	48.5	(43.0 to 54.0)
Centre	50.0	8.8	50.4	(46.9 to 53.9)
Wing	46.5	12.0	45.4	(42.6 to 48.2)
Fullback	47.4	11.9	42.8	(38.2 to 47.3)

Table 25: Vertical jump height scores of rugby league participants by participation level.

	cm	**±SD**
Junior Elite[102]	51.6	7.7
Junior Sub-Elite[102]	46.9	6.8
Amateur[70]	38.1	7.1
Semi-Professional[74]	42.5	8.8

Changes over a season

Most, but not all[82, 207] studies examining the physiological and anthropometric characteristics of rugby league participants have done so as a cross sectional analysis only. Studies undertaking a longitudinal review of the physiological and anthropometric changes of rugby league participants have highlighted the changes that occur as the season progresses for amateur,[82] semi-professional[45] and junior elite[86] rugby league. The early part of the season is reported to be the period where the greatest improvements occur[86] but this reportedly deteriorates as the season progresses (see Table 26). This has been attributed to high training loads that participants undergo in preparation for the competition season whereas reductions in training loads throughout the season have been reported to attribute to the deterioration of the participants fitness improvements.[86]

Table 26: Body mass, sum of skinfolds, muscular power, speed, agility and estimated maximal aerobic power of rugby league participants during a competitive season by participation level.

		Off-Season		Pre-Season		Mid-Season		End-Season	
		mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Body Mass (kg)	Amateur[82]	84.2	(78.3 to 90.0)	82.0	(76.4 to 87.5)	84.5	(79.0 to 90.1)	86.2	(80.7 to 91.7)
	Junior[86]	83.3	(72.2 to 94.3)	79.9	(74.1 to 85.8)	78.2	(72.8 to 83.7)	79.0	(73.7 to 84.4)
Sum of Skinfolds (mm)	Amateur[82]	90.7	(78.1 to 103.2)	84.7	(73.2 to 96.2)	84.3	(71.2 to 97.4)	93.4	(82.1 to 104.7)
	Junior[86]	93.9	(71.4 to 116.4)	85.2	(72.8 to 97.7)	83.6	(72.1 to 95.0)	84.4	(73.4 to 95.4)
10-m Sprint (s)	Amateur[82]	1.83	(1.78 to 1.89)	1.85	(1.81 to 1.89)	1.80	(1.77 to 1.83)	1.80	(1.77 to 1.83)
	Junior[86]	1.82	(1.75 to 1.90)	1.85	(1.81 to 1.88)	1.82	(1.78 to 1.86)	1.79	(1.76 to 1.82)
20-m Sprint (s)	Amateur[82]	3.15	(3.05 to 3.24)	3.12	(3.06 to 3.19)	3.13	(3.08 to 3.18)	3.10	(3.06 to 3.14)
	Junior[86]	3.12	(2.99 to 3.25)	3.11	(3.05 to 3.17)	3.13	(3.06 to 3.19)	3.09	(3.05 to 3.13)
40-m Sprint (s)	Amateur[82]	5.61	(5.43 to 5.79)	5.61	(5.48 to 5.74)	5.62	(5.52 to 5.72)	5.53	(5.46 to 5.61)
	Junior[86]	5.56	(5.30 to 5.82)	5.58	(5.76 to 5.92)	5.64	(5.51 to 5.77)	5.52	(5.45 to 5.58)
Agility (s)	Amateur[82]	6.03	(5.88 to 6.18)	5.92	(4.82 to 5.02)	5.95	(5.74 to 6.16)	5.94	(5.82 to 6.06)
	Junior[86]	5.93	(5.71 to 6.14)	5.84	(5.76 to 5.92)	5.55	(5.28 to 5.81)	5.82	(5.70 to 5.94)
Vertical Jump (cm)	Amateur[82]	55.4	(52.1 to 58.8)	58.6	(56.0 to 61.2)	55.7	(53.2 to 58.1)	55.5	(53.6 to 57.4)
	Junior[86]	54.8	(50.4 to 59.2)	58.2	(56.0 to 60.3)	56.8	(54.2 to 59.5)	57.8	(55.7 to 60.0)
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	Amateur[82]	42.0	(38.8 to 45.1)	48.5	(46.1 to 50.9)	51.3	(49.6 to 52.9)	49.6	(47.5 to 51.7)
	Junior[86]	43.7	(39.9 to 47.5)	50.6	(48.5 to 52.8)	53.5	(51.7 to 55.3)	52.1	(50.5 to 53.8)

Data reported as means (95% confidence interval). VO_2max = maximal aerobic power

Part 4: Risk factors for injury in rugby league

Participation level

The injury rate in professional competitions has been reported to be between 214 per 1000 playing hours[58] to 544 per 1000 playing hours.[134] The injury rates in professional competitions are reported to be amongst the highest of all team events.[119] This has been correlated to rule changes and player fitness requirements.[78-80, 114, 122, 192, 197, 230] These include changes in playing season from a winter to a summer competition (European Super-League [ESL]),[119, 121, 134, 137] the switch to the Super-League competition format and changes in the rules for the National Rugby League (NRL).

Semi-professional injury rate is reported to be between 115[149, 153] to 825[77, 78] per 1000 playing hours. Despite the different total number of injuries, when comparing missed match injury incidence the studies had similar injury rates (78 per 1000 playing hours vs. 68 per 1000 playing hours).[77] The higher injury rate of the original semi-professional study has been attributed to three main attributions:[77, 81] (1) Changes in playing and training intensity in comparison to amateur; (2) Subtle variations in rules; and (3) Environmental conditions (e.g., climate and ground conditions). Other factors thought to contribute to the higher injury rate are increases in player fitness over amateur players and a moderate skill level in comparison to professional players.[80]

Amateur rugby league injuries occur primarily in the second half of matches.[69, 87, 104] This has been suggested to occur due to fatigue, or fatigue-induced reduction in skill, as a strong contributor to the injury rate at amateur level participation.[69, 87, 104] The lower VO_2max of participants at this level of involvement could explain the high rate of the injuries.[70, 87, 104] However, poor decision making ability under fatigued conditions may also be a contributor to the rate of injuries.[70, 87, 104]

Injury rate in junior rugby league has been recorded from 1 per 1000 playing hours[213] (under 8 year olds) to 406 per 1000 playing hours[58] (under 19 year olds). This increase paralleled the participant's biological maturity.[58, 213] The greatest increase was seen in the under 13 and 15 age group.[213] The injury rates also increased as the playing level increased. Influencing factors are increases in speed,[98] body mass[98] and greater impact forces between players.[213] Injury rate has also been attributed to low skill and low fitness components of junior competitions[77, 78] when compared with semi-professional and professional rugby league.

In conclusion, the variations in injury rate amongst the different participation levels have been attributed to three main factors: (1) Increasing fitness levels; (2) Variations in skill levels; and (3) Different body weight/fat distributions.[58, 69, 70, 73, 75, 77, 78, 80, 81, 98, 114, 118, 120, 230] It has also been suggested that pre-existing injury and player fatigue may also contribute factor to match injuries.[58, 69, 72, 73, 77, 78, 80, 81, 87]

Physiological factors

Amateur rugby league participants are reported to have a lower fitness and skill component compared to other participation levels.[78] Semi-professional participants are described as having a higher fitness level than amateurs but a lowered skill level when compared with professional players.[77, 78] Professional participants have been described as having a high fitness and skill component in comparison to other participation levels.[78] One thought is that as participant fitness and skill levels increase there should be a decrease in injury rate. This has not occurred as semi-professional participants recorded the highest rate of injury.[77]

Physiological factors such as match intensity,[73, 78, 85, 104, 193, 198] training (intensity and load)[76, 77, 81, 97, 151, 181] and fatigue[69] have also been suggested as risk factors[96] and may contribute to rugby league injuries.

Match intensity

Gabbett[69] reported that the rate of injury increased over three years in an amateur rugby league competition from 151 per 1000 playing hours in 1995 to 179 per 1000 playing hours in 1997.[73] This injury rate increase occurred despite the season and playing rules remaining similar. These increases were attributed to playing intensity increasing each year.[73] Although an injury sustained at one body site may have contributed to an injury at another site.[73] This is important as incomplete injury rehabilitation is a concern for participants returning to sport. No study has been published on rugby league recurrent or subsequent injuries. Studies in soccer have shown a strong correlation between previous injuries, incomplete rehabilitation and subsequent injury occurrence.[162]

Changes in the interchange rules occurred in the 2000–01 off season from an unlimited interchange to a 12 person interchange of the four reserves in the team.[104] Under the unlimited interchange rule there were more players identified as leaving the field through injury than under the limited interchange rule.[198] Regardless of the appearance that this assisted in the reduction of injuries in the match, there was an increase (13%) of professional participants missing the subsequent match through injury.[193] Despite this, Gabbett[85] identified a relative risk reduction of 30% in sub elite rugby league participants following the introduction of the limited interchange rule. It was hypothesised that this rule change increased the physiological demands of participants resulting in a reduced match speed and minimising the impact forces associated with the physical collisions and tackles in rugby league matches.[85]

Training intensity and type

Data from semi-professional participation identified that the majority of rugby league training injuries occurred in the early stages of the season.[77, 81] The injury rate was 2.6-fold higher in the early season when compared with the average seasonal injury rate (116 per 1000 training hours vs. 45 per 1000 training hours).[77] Training injuries were significantly correlated ($r=0.86$) with an increase in training loads suggesting that harder training sessions increase the risk of training injuries occurring.[80] Increases in training load during the early competition training phase have been related to a decrease in agility of participants.[97]

A reduction in training duration and training intensity by 11% to 16% was associated with a 40% – 50% reduction in training injury rates. Despite the reduction of the training load and duration, participants VO_{2MAX} increased progressively at the sub-elite level of participation. These findings were reported to suggest that reductions in training load during the early-competition training phase may reduce the injury risk without compromising agility performances.

Traditional training activities such as shuttle drills over 10-m for periods up to 90 seconds, repeated tackling efforts for 5 to 10 repetitions and sprints covering five to 60 metres with varying work-rest ratios have been suggested as specific training activities for rugby league.[181] These types of training activities have recorded the majority of training injuries in both semi-professional[76] and amateur[151] participants. Often these training activities involve no skill component (i.e. running without the ball) and can be seen to be of a physical training nature only.[76]

More recently skill-based training conditioning activities have been introduced into the training routine of rugby league participants.[76, 151] These activities have been used to develop the skill and fitness of rugby league participants with the added opportunity of the development of decision-making and problem-solving skills of the participants.[76] Additionally, skill-based conditioning activities have been reported to reduce the rate of injuries in both semi-professional[76] and amateur[151] participants and have been reported to emulate the same physiological responses (i.e., mean heart rate and blood lactate responses) as those obtained during competition matches.

Other risk factors

The identification of injury risk factors is the key dependant to the successful implementation and evaluation of effective injury prevention strategies.[63, 244] Although low training frequency and player fitness are reported as risk factors for injury in rugby union[96, 165, 208] and rugby league[96] only one study to date has investigated the risk factors for rugby league injuries. [96] This study identified that there were several injury risk factors for injury in rugby league participants. These are:

- Low speed and maximal aerobic power (VO_{2MAX});
- Completing less than 18 weeks pre-season training before their first injury have an increased risk of subsequent injuries;
- Increased playing intensity and fitness levels;
- Increased training session's leading to residual fatigue and higher risk of injury; and
- Players with more than 15 years rugby league experience have a higher injury severity.

These findings support the suggestion that fatigue, or fatigue-induced reduction in skill, is a strong contributor to the rate of injuries in rugby league participants.[69] These findings also highlight that speed and endurance training is important in the reduction of the rate of injury in rugby league participants.[96]

Part 5: Future injury research for rugby league activities

The following suggestions are forwarded for consideration by the New Zealand Rugby league (NZRL) as part of the process for identification of injuries that occur as a result of participation in rugby league activities. As identified by van Mechelen[244] and Finch[63] the implementation and evaluation of effective injury prevention strategies is dependant on the identification of the injury risk factors. Although there are a number of studies that have been published on rugby league activities and physiological and anthropometric aspects of participants, there is a paucity of studies looking at rugby league in New Zealand. As has been shown when comparing semi-professional[153] participation injury rates, there are some noticeable differences that have been recorded that may be due to a combination of factors yet to be fully identified.

Injury fact sheets

The studies to date are able to provide a wide range of data available for pooling into an information sheet available from the NZRL. This data could include the identified injury rates for all injury types, sites, occurrence and known injury risk factors. A pooled analysis of the anthropometric and physiological assessments and testing results would provide a guideline for the assessment of rugby league participants. A suggestion would be for the NZRL to make a double-sided A4 sheet available with the information identified above as part of their continuing education commitment to the districts, coaches and trainers programmes.

Effects of injuries on the amateur participant

While the health and financial costs of injuries have been documented previously,[72, 182] the effects of an injury on the amateur participant has not been explored or identified. Although the ACC system can provide some of the financial medical costs, the socioeconomic costs of the injured participant may assist in identifying appropriate rehabilitation processes and assist in providing for a more supportive return to sport and work process to be established. Research into the effects of the injured participants is warranted to identify the full effects of an injury occurring on the rugby league participant.

Injury rate

Despite several studies and associated reviews having been completed on the injury rate of rugby league participants at various levels of participation, there are relatively few studies looking at the New Zealand injury rate from rugby league participation. Most, but not all New Zealand based studies have used either a single team,[151, 152] a self reporting injury process,[185] a national competition,[148, 154] national tournament[150] or ACC[169] data to report the injury rate of participants in New Zealand. Only one prospective multi-team study[149, 153] has ever been undertaken in New Zealand but this was only over one season and is limited to a particular level of participation. Gissane et al.[118] conducted a pooled data analysis on professional participants England to establish a more accurate estimate of the injury rate and this is may be useful at the amateur (junior and senior) and elite levels of participation. This could include recording a larger data size (perhaps all teams in a competition) for future rugby league injury surveillance studies.

Recurrent and subsequent injuries

To date no one has conducted a study looking at rugby league recurrent or subsequent injuries. Studies conducted in soccer[127] and rugby union[109] have identified a correlation between pre-existing injury from the previous participation season and subsequent injuries. Further studies investigating the effects of a previous injury on subsequent and recurrent injuries is clearly required to assist in the identification in risk factors at the amateur rugby league participation level.

Women's rugby league

There have been only two published studies on female participation in rugby league.[91, 150] One study[150] looked at the injury rate during a national tournament while the other study[91] recorded the physiological and anthropometric aspects of female participants at the elite level of participation. The injury rate study is limited as it looks at several matches played twice a day over four days while the elite anthropometric study looked at one team at one event. To enable a more complex analysis of the anthropometric and physiological characteristics of the female participant in rugby league, as well as the true injury rate from women's participation in rugby league activities more longitudinal studies are clearly required.

Junior rugby league

There is a paucity of studies looking at junior rugby league injury rates. Most, but not all junior rugby league studies have used a specific age grade at the expense of other junior participants. As with senior rugby league injury studies, most studies in junior rugby league injuries have been over one participation year and have not taken into account the inter-seasonal variability that may occur. These studies have also used a small cohort that may result in the data not being applicable to all junior rugby league participants. Longitudinal studies looking at the injury rate over a wider spectrum of junior participants are clearly required to gain a better understanding of the injury rate for junior rugby league participants.

Anthropometric and physiological aspects

Of all the anthropometric and physiological studies on rugby league participants that have been published, none have been on New Zealand based rugby league participants. One unpublished study that recorded the anthropometric and physiological aspects of semi-professional participants found some similarities but this was limited to a pre-season assessment. Studies looking at the anthropometric and physiological changes over participation seasons of various levels of rugby league participation would assist in broadening the world wide knowledge of the effects of participation in rugby league activities.

Appendix 2. **Sample of a participant consent form.**

Consent to Participation in Research

Title of Project: **Injuries in rugby league: Return to play decisions.**

Project Supervisor: **Professor Patria Hume**

Researcher: **Doug King**

- I have read and understood the information provided about this research project (Information Sheet dated 23rd May 2008).
- I have had an opportunity to ask questions and to have them answered.
- I agree to participating in the research.
- I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant information will be destroyed.
- I agree to take part in this research.
- I wish to receive a copy of the report from the research: tick one: Yes O No O

Signature: ....

Name: ....

Date: ....

Project Supervisor Contact Details:
Professor Patria Hume
Institute of Sport & Recreation Research New Zealand
School of Sport and Recreation
Auckland University of Technology
Private Bag 92006
Auckland 1020
Ph 917 9999 ext. 7306
patria.hume@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on xx/ xxx/ xxxx
AUTEC Reference number **xx/xx**

Appendix 3. Sample of a participant information pack.

Participant Information Sheet

Date Information Sheet Produced: 4th February 2008

AUCKLAND UNIVERSITY OF TECHNOLOGY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project Title

Injuries in Rugby League: Return to play decisions.

Invitation to participate

You are invited to take part in the above mentioned research project. Your participation in this research is voluntary. You are free to withdraw consent and discontinue participation at anytime without influencing any present and/or future involvement with the Auckland University of Technology.

Your consent to participate in this research will be indicated by your signing and dating the consent form. Signing the consent form indicates that you have freely given your consent to participate, and that there has been no coercion or inducement to participate by the researchers from AUT.

What is the purpose of the study?

The purpose of the study is to record and report identifiable influences for the return of participants to match and training activities following an injury.

This study is being conducted as part of a PhD degree. The results of this study will be presented at national / international conferences and submitted to peer-reviewed journals.

How was I chosen to be asked to participate in the study?

Those people who participate in rugby league activities as part of the competition under the administration of the Wellington Rugby League are invited to participate in the research.

What happens in the study?

Players identified as having been injured will be asked to complete two questionnaires as to the reasons why they have returned to participating in rugby league activities.

What are the discomforts and risks?

Only those discomforts and risks that normally occur from participating in rugby league activities.

What are the benefits?

Information gained from this research has potential to help shape training strategies, and develop prognostic indicators of value to athletes, clinicians, physical conditioners and coaches.

What compensation is available for injury or negligence?

Compensation is available through the Accident Compensation Corporation within its normal limitations

How is my privacy protected?

The data from the project (will be coded and held anonymously in secure storage under the responsibility of the principal investigator of the study in accordance with the requirements of the New Zealand Privacy Act (1993).

All reference to participants will be by code number only in terms of the research thesis and publications. Identification information will be stored on a separate file and computer from that containing the actual data. In the case of any video footage, subject's faces will be obscured / blanked out.

Only the investigators will have access to computerised data.

What are the costs of Participating?

Participating in this research project will not cost you apart from your time that you normally provide for participating in rugby league activities..

Opportunity to consider invitation

Please take the necessary time you need to consider the invitation to participate in this research.

It is reiterated that your participation in this research is completely voluntary.

If you require further information about the research topic please feel free to contact Peter Maulder (details are at the bottom of this information sheet).

You may withdraw from the study at any time without there being any adverse consequences of any kind

You may ask for a copy of you results at any time and you have the option of requesting a report of the research outcomes at the completion of the study.

How do I join the study?

If you are interested in participating in this research please feel free to contact Doug King (details are at the bottom of this information sheet).

Participant concerns

If you have any questions please feel free to contact Peter Maulder or Associate Professor Patria Hume. Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor – Professor Patria Hume. Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, madeline.banda@aut.ac.nz , 917 9999 ext 8044.

Researcher Contact Details: Doug King, Institute of Sport and Recreation Research New Zealand, School of Sport and Recreation, Auckland University of Technology. **Email:** doug.king@aut.ac.nz or phone +64 4 589 1816.

Project Supervisor Contact Details: Professor Patria Hume, Institute of Sport and Recreation Research New Zealand, School of Sport and Recreation, Auckland University of Technology. Email: patria.hume@aut.ac.nz or phone +64 9 921 9999 ext 7306.

*Approved by the Auckland University of Technology Ethics Committee on *** of ***, **** AUTEC Reference number **/***

Appendix 4: Chapters 3, 4, 5, 6, 7,8, 12 and 13 ethics approvals

Chapter 3, 4, 5, 6 7 and 8 Ethics approval

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

M E M O R A N D U M

Auckland University of Technology Ethics Committee (AUTEC)

To:Patria Hume
From:**Madeline Banda** Executive Secretary, AUTEC
Date:26 March 2008
Subject: Ethics Application Number 08/30 **The incidence, site and type of injuries that occur to different ethnic groups as a result of participation in rugby league activities.**

Dear Patria

I am pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 10 March 2008. Your application is now approved for a period of three years until 10 March 2011.

I advise that as part of the ethics approval process, you are required to submit to AUTEC the following:

- A brief annual progress report using form EA2, which is available online through *http://www.aut.ac.nz/about/ethics*. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 10 March 2011;
- A brief report on the status of the project using form EA3, which is available online through *http://www.aut.ac.nz/about/ethics*. This report is to be submitted either when the approval expires on 10 March 2011 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this. Also, if your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within that jurisdiction.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at charles.grinter@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the AUTEC and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Madeline Banda
Executive Secretary
Auckland University of Technology Ethics Committee

M E M O R A N D U M

Auckland University of Technology Ethics Committee (AUTEC)

To:Patria Hume
From:**Madeline Banda** Executive Secretary, AUTEC
Date:26 March 2008
Subject: Ethics Application Number 08/44 **Injuries in Rugby League: incidence, limb dominance effects, and return to play decisions.**

Dear Patria

I am pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 10 March 2008, subject to the following conditions:

1. Revision of the consent processes given in the response to section D.7 of the application, providing for the individual players and the trainers, as well as the club, to give written consent for their participation and including separate Information Sheets and Consent Forms for each category.

I request that you provide the Ethics Coordinator with a written response to the points raised in these conditions at your earliest convenience, indicating either how you have satisfied these points or proposing an alternative approach. AUTEC also requires written evidence of any altered documents, such as Information Sheets, surveys etc. Once this response and its supporting written evidence has been received and confirmed as satisfying the Committee's points, you will be notified of the full approval of your ethics application.

When approval has been given subject to conditions, full approval is not effective until *all* the concerns expressed in the conditions have been met to the satisfaction of the Committee. Data collection may not commence until full approval has been confirmed. Should these conditions not be satisfactorily met within six months, your application may be closed and you will need to submit a new application should you wish to continue with this research project.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at charles.grinter@aut.ac.nz or by telephone on 921 9999 at extension 8860.

Yours sincerely

Madeline Banda
Executive Secretary
Auckland University of Technology Ethics Committee
Cc:Doug King doug.king@aut.ac.nz

Health and Disability Ethics Committees

Central Regional Ethics Committee
Ministry of Health
Level 2, 1–3 The Terrace
PO Box 5013
Wellington
Phone: (04) 496 2405
Fax: (04) 496 2191
Email: central_ethicscommittee@moh.govt.nz

26 February 2010

Mr Doug King
12 Freyberg Street
Waterloo
Lower Hutt

Dear Mr Doug King

Ethics ref: **CEN/09/56/EXP**
Study title: Injury Knowledge of Rugby League Coaches: A District Experience
Investigators: Mr Doug King

The above study has been given ethical approval by the Central Regional Ethics Committee.

Accreditation
The Committee involved in the approval of this study is accredited by the Health Research Council and is constituted and operates in accordance with the Operational Standard for Ethics Committees, April 2006.

Final Report
The study is approved until 30/09/2010. A final report is required at the end of the study and a form to assist with this is available at http://www.ethicscommittees.health.govt.nz. If the study will not be completed as advised, please forward a progress report and an application for extension of ethical approval one month before the above date.

Amendments
It is also a condition of approval that the Committee is advised of any adverse events, if the study does not commence, or the study is altered in any way, including all documentation eg advertisements, letters to prospective participants.

Please quote the above ethics committee reference number in all correspondence.

It should be noted that Ethics Committee approval does not imply any resource commitment or administrative facilitation by any healthcare provider within whose facility the research is to be carried out. Where applicable, authority for this must be obtained separately from the appropriate manager within the organisation.

We wish you well with your study.

Yours sincerely

S Scott
Sonia Scott
Administrator
Central Regional Ethics Committee

Administered by the Ministry of Health   Approved by the Health Research Council   http://www.ethicscommittees.health.govt.nz

Appendix 5: Supplemental data for Chapter 9

Nature of tackles in professional rugby league

Tackle data for International, National Rugby League and National Youth Competition competitions

Table 1: Total tackles by number of tacklers, tackle height, degree of tackler position, tackle number and field position per 1000 tackle events and per match with 95% Confidence Intervals and percentages

		No.	Rate expressed per: 1000 tackle events Rate (95% CI)	1000 match hours Rate (95% CI)	Match Rate (95% CI)	%
Total		50019	1000.0 (991.3 to 1008.8)	18080.9 (17923.1 to 18240.1)	625.2 (619.8 to 630.7)	100.0
	First half	25334	506.5 (500.3 to 512.8)	9157.8 (9045.7 to 9271.3)	316.7 (312.8 to 320.6)	50.7
	Second Half	24685	493.5 (487.4 to 499.7)	8923.1 (8812.5 to 9035.1)	308.6 (304.7 to 312.4)	49.3
Number of tacklers						
	1	8877	177.5 (173.8 to 181.2)	3208.9 (3142.8 to 3276.3)	111.0 (108.7 to 113.3)	17.7
	2	22884	457.5 (451.6 to 463.5)	8272.1 (8165.6 to 8380.0)	286.1 (282.4 to 289.8)	45.8
	3	16372	327.3 (322.3 to 332.4)	5918.2 (5828.2 to 6009.5)	204.7 (201.5 to 207.8)	32.7
	4 or more	1886	37.7 (36.0 to 39.4)	681.8 (651.7 to 713.2)	23.6 (22.5 to 24.7)	3.8
Tackle height						
	Head/Neck	4499	46.9 (45.5 to 48.3)	1626.3 (1579.5 to 1674.5)	56.2 (54.6 to 57.9)	4.7
	Shoulder	10755	112.1 (110.0 to 114.2)	3887.7 (3814.9 to 3961.9)	134.4 (131.9 to 137.0)	11.2
	Mid Torso	32788	341.8 (338.1 to 345.5)	11852.2 (11724.6 to 11981.2)	409.9 (405.4 to 414.3)	34.2
	Hip / Thigh	34654	361.2 (357.4 to 365.0)	12526.7 (12395.5 to 12659.3)	433.2 (428.6 to 437.8)	36.1
	Lower Legs	13241	138.0 (135.7 to 140.4)	4786.4 (4705.5 to 4868.6)	165.5 (162.7 to 168.4)	13.8
Degree of tackler position						
	300°-330°	16199	176.7 (174.0 to 179.4)	5855.6 (5766.1 to 5946.5)	202.5 (199.4 to 205.6)	17.7
	330°-360°	8549	93.2 (91.3 to 95.2)	3090.3 (3025.5 to 3156.5)	106.9 (104.6 to 109.2)	9.3
	000°-030°	9970	108.7 (106.6 to 110.9)	3604.0 (3533.9 to 3675.4)	124.6 (122.2 to 127.1)	10.9
	030°-060°	16890	184.2 (181.5 to 187.0)	6105.4 (6014.0 to 6198.2)	211.1 (208.0 to 214.3)	18.4
	060°-300°	40071	437.1 (432.8 to 441.4)	14484.9 (14343.8 to 14627.4)	500.9 (496.0 to 505.8)	43.7
Tackle No.						
	Tackle 0	883	17.7 (16.5 to 18.9)	319.2 (298.8 to 341.0)	11.0 (10.3 to 11.8)	1.8
	Tackle 1	12166	243.2 (238.9 to 247.6)	4397.8 (4320.3 to 4476.6)	152.1 (149.4 to 154.8)	24.3
	Tackle 2	10382	207.6 (203.6 to 211.6)	3752.9 (3681.4 to 3825.8)	129.8 (127.3 to 132.3)	20.8
	Tackle 3	8832	176.6 (172.9 to 180.3)	3192.6 (3126.7 to 3259.9)	110.4 (108.1 to 112.7)	17.7
	Tackle 4	6874	137.4 (134.2 to 140.7)	2484.8 (2426.8 to 2544.3)	85.9 (83.9 to 88.0)	13.7
	Tackle 5	4460	89.2 (86.6 to 91.8)	1612.2 (1565.6 to 1660.2)	55.8 (54.1 to 57.4)	8.9
	Tackle 6	217	4.3 (3.8 to 5.0)	78.4 (68.7 to 89.6)	2.7 (2.4 to 3.1)	0.4
	Incomplete Tackle	6205	124.1 (121.0 to 127.2)	2243.0 (2187.9 to 2299.5)	77.6 (75.7 to 79.5)	12.4
Field Position						
Defence	In Goal	396	7.9 (7.2 to 8.7)	143.1 (129.7 to 158.0)	5.0 (4.5 to 5.5)	0.8
Defence	0-10	1620	32.4 (30.8 to 34.0)	585.6 (557.8 to 614.8)	20.3 (19.3 to 21.3)	3.2
Defence	10-20	5401	108.0 (105.1 to 110.9)	1952.4 (1901.0 to 2005.1)	67.5 (65.7 to 69.3)	10.8
Defence	20-30	6513	130.2 (127.1 to 133.4)	2354.3 (2297.8 to 2412.2)	81.4 (79.5 to 83.4)	13.0
Defence	30-40	7084	141.6 (138.4 to 145.0)	2560.7 (2501.8 to 2621.1)	88.6 (86.5 to 90.6)	14.2
Defence	40-50	6156	123.1 (120.0 to 126.2)	2225.3 (2170.4 to 2281.6)	77.0 (75.1 to 78.9)	12.3
Attack	50-40	4720	94.4 (91.7 to 97.1)	1706.2 (1658.2 to 1755.6)	59.0 (57.3 to 60.7)	9.4
Attack	40-30	3989	79.7 (77.3 to 82.3)	1441.9 (1397.9 to 1487.4)	49.9 (48.3 to 51.4)	8.0
Attack	30-20	3956	79.1 (76.7 to 81.6)	1430.0 (1386.1 to 1475.3)	49.5 (47.9 to 51.0)	7.9
Attack	20-10	3754	75.1 (72.7 to 77.5)	1357.0 (1314.3 to 1401.1)	46.9 (45.4 to 48.5)	7.5
Attack	10-0	5966	119.3 (116.3 to 122.3)	2156.6 (2102.6 to 2212.0)	74.6 (72.7 to 76.5)	11.9
Attack	In Goal	464	9.3 (8.5 to 10.2)	167.7 (153.1 to 183.7)	5.8 (5.3 to 6.4)	0.9

Table 2: Total tackles by tackler and ball carrier for player position, player group and forwards and backs per 1000 tackle events and per match with 95% Confidence Intervals and percentages

	No.	Rate expressed per 1000 tackle events Rate (95% CI)	1000 match hours Rate (95% CI)	Match Rate (95% CI)	%
Player as tackler.					
1. Fullback	1607	29.1 (27.7 to 30.5)	580.9 (553.2 to 610.0)	20.1 (19.1 to 21.1)	2.9
2. Wing	1292	23.4 (22.1 to 24.7)	467.0 (442.2 to 493.2)	16.2 (15.3 to 17.1)	2.3
3. Centre	2679	48.5 (46.7 to 50.4)	968.4 (932.4 to 1005.8)	33.5 (32.2 to 34.8)	4.8
4. Centre	3895	70.5 (68.3 to 72.7)	1408.0 (1364.4 to 1452.9)	48.7 (47.2 to 50.2)	7.0
5. Wing	927	16.8 (15.7 to 17.9)	335.1 (314.2 to 357.4)	11.6 (10.9 to 12.4)	1.7
6. Stand Off	5891	106.6 (103.9 to 109.4)	2129.5 (2075.8 to 2184.6)	73.6 (71.8 to 75.5)	10.7
7. Half back	3858	69.8 (67.7 to 72.1)	1394.6 (1351.3 to 1439.3)	48.2 (46.7 to 49.8)	7.0
8. Prop	4824	87.3 (84.9 to 89.8)	1743.8 (1695.3 to 1793.7)	60.3 (58.6 to 62.0)	8.7
9. Hooker	8138	147.3 (144.1 to 150.5)	2941.7 (2878.5 to 3006.3)	101.7 (99.5 to 104.0)	14.7
10. Prop	4986	90.2 (87.8 to 92.8)	1802.3 (1753.0 to 1853.1)	62.3 (60.6 to 64.1)	9.0
11. second row	3997	72.3 (70.1 to 74.6)	1444.8 (1400.7 to 1490.3)	50.0 (48.4 to 51.5)	7.2
12. Second row	6654	120.4 (117.6 to 123.3)	2405.3 (2348.2 to 2463.8)	83.2 (81.2 to 85.2)	12.0
13. Loose Forward	6509	117.8 (115.0 to 120.7)	2352.9 (2296.4 to 2410.7)	81.4 (79.4 to 83.4)	11.8
Outside Backs	10400	188.2 (184.6 to 191.9)	3759.4 (3687.8 to 3832.4)	130.0 (127.5 to 132.5)	18.8
Adjustables	24396	441.5 (436.0 to 447.1)	8818.7 (8708.7 to 8930.0)	305.0 (301.1 to 308.8)	44.2
Hit Up Forwards	20461	370.3 (365.2 to 375.4)	7396.3 (7295.6 to 7498.3)	255.8 (252.3 to 259.3)	37.0
Forwards	35108	635.4 (628.7 to 642.0)	12690.9 (12558.8 to 12824.3)	438.9 (434.3 to 443.5)	63.5
Backs	20149	364.6 (359.6 to 369.7)	7283.5 (7183.6 to 7384.7)	251.9 (248.4 to 255.4)	36.5
Player as ball carrier					
1. Fullback	2649	53.0 (51.0 to 55.0)	957.6 (921.8 to 994.7)	33.1 (31.9 to 34.4)	10.4
2. Wing	2180	43.6 (41.8 to 45.5)	788.0 (755.6 to 821.8)	27.3 (26.1 to 28.4)	8.6
3. Centre	1996	39.9 (38.2 to 41.7)	721.5 (690.5 to 753.9)	25.0 (23.9 to 26.1)	7.9
4. Centre	2049	41.0 (39.2 to 42.8)	740.7 (709.3 to 773.4)	25.6 (24.5 to 26.7)	8.1
5. Wing	2282	45.6 (43.8 to 47.5)	824.9 (791.7 to 859.4)	28.5 (27.4 to 29.7)	9.0
6. Stand Off	1350	27.0 (25.6 to 28.5)	488.0 (462.6 to 514.7)	16.9 (16.0 to 17.8)	5.3
7. Half back	1212	24.2 (22.9 to 25.6)	438.1 (414.1 to 463.5)	15.2 (14.3 to 16.0)	4.8
8. Prop	2365	47.3 (45.4 to 49.2)	854.9 (821.1 to 890.1)	29.6 (28.4 to 30.8)	9.3
9. Hooker	1220	24.4 (23.1 to 25.8)	441.0 (416.9 to 466.5)	15.3 (14.4 to 16.1)	4.8
10. Prop	2108	42.1 (40.4 to 44.0)	762.0 (730.2 to 795.2)	26.4 (25.2 to 27.5)	8.3
11. second row	2325	46.5 (44.6 to 48.4)	840.4 (807.0 to 875.3)	29.1 (27.9 to 30.3)	9.2
12. Second row	2040	40.8 (39.1 to 42.6)	737.4 (706.1 to 770.1)	25.5 (24.4 to 26.6)	8.0
13. Loose Forward	1606	32.1 (30.6 to 33.7)	580.5 (552.8 to 609.6)	20.1 (19.1 to 21.1)	6.3
Outside Backs	11156	439.5 (431.4 to 447.8)	4032.7 (3958.5 to 4108.2)	139.5 (136.9 to 142.1)	44.0
Adjustables	5388	212.3 (206.7 to 218.0)	1947.7 (1896.3 to 2000.4)	67.4 (65.6 to 69.2)	21.2
Hit Up Forwards	8838	348.2 (341.0 to 355.5)	3194.8 (3128.8 to 3262.1)	110.5 (108.2 to 112.8)	34.8
Forwards	11664	233.2 (229.0 to 237.5)	4216.3 (4140.5 to 4293.5)	145.8 (143.2 to 148.5)	46.0
Backs	13718	274.3 (269.7 to 278.9)	4958.8 (4876.5 to 5042.5)	171.5 (168.6 to 174.4)	54.0

Table 3: Tackles at International level of participation by number of tacklers, tackle height, degree of tackler position, tackle number and field position per 1000 tackle events and per match with 95% Confidence Intervals and percentages

		No.	Rate expressed per 1000 tackle events Rate (95% CI)	Rate expressed per 1000 match hours Rate (95% CI)	Rate expressed per Match Rate (95% CI)	%
Total		12412	1000.0 (982.6 to 1017.7)	17946.8 (17633.8 to 18265.3)	620.6 (609.8 to 631.6)	100.0
	First half	6194	499.0 (486.8 to 511.6)	8956.0 (8735.8 to 9181.9)	309.7 (302.1 to 317.5)	49.9
	Second half	6218	501.0 (488.7 to 513.6)	8990.7 (8770.0 to 9217.0)	310.9 (303.3 to 318.7)	50.1
Number of Tacklers						
	1	2271	183.0 (175.6 to 190.7)	3283.7 (3151.4 to 3421.6)	113.6 (109.0 to 118.3)	18.3
	2	5556	447.6 (436.0 to 459.6)	8033.5 (7825.1 to 8247.6)	277.8 (270.6 to 285.2)	44.8
	3	4064	327.4 (317.5 to 337.6)	5876.2 (5698.3 to 6059.7)	203.2 (197.0 to 209.5)	32.7
	4 or more	521	42.0 (38.5 to 45.7)	753.3 (691.3 to 820.9)	26.1 (23.9 to 28.4)	4.2
Tackle Height						
	Head/Neck	1811	77.2 (73.7 to 80.9)	2618.6 (2500.7 to 2742.0)	90.6 (86.5 to 94.8)	7.7
	Shoulder	2169	92.5 (88.7 to 96.5)	3136.2 (3007.0 to 3271.0)	108.5 (104.0 to 113.1)	9.2
	Mid Torso	6818	290.7 (283.9 to 297.7)	9858.3 (9627.0 to 10095.1)	340.9 (332.9 to 349.1)	29.1
	Hip / Thigh	8627	367.8 (360.1 to 375.7)	12474.0 (12213.5 to 12740.0)	431.4 (422.3 to 440.5)	36.8
	Lower Legs	4029	171.8 (166.6 to 177.2)	5825.6 (5648.5 to 6008.3)	201.5 (195.3 to 207.8)	17.2
Degree of Tackler Position						
	300°-330°	4484	190.0 (184.6 to 195.7)	6483.5 (6296.5 to 6676.1)	224.2 (217.7 to 230.9)	19.0
	330°-360°	3219	136.4 (131.8 to 141.2)	4654.4 (4496.4 to 4818.0)	161.0 (155.5 to 166.6)	13.6
	000°-030°	2718	115.2 (110.9 to 119.6)	3930.0 (3785.0 to 4080.6)	135.9 (130.9 to 141.1)	11.5
	030°-060°	3766	159.6 (154.6 to 164.8)	5445.3 (5274.2 to 5622.1)	188.3 (182.4 to 194.4)	16.0
	060°-300°	9407	398.7 (390.7 to 406.8)	13601.8 (13329.7 to 13879.5)	470.4 (460.9 to 480.0)	39.9
Tackle No.						
	Tackle 0	172	13.9 (11.9 to 16.1)	248.7 (214.2 to 288.8)	8.6 (7.4 to 10.0)	1.4
	Tackle 1	2895	233.2 (224.9 to 241.9)	4185.9 (4036.2 to 4341.2)	144.8 (139.6 to 150.1)	23.3
	Tackle 2	2532	204.0 (196.2 to 212.1)	3661.1 (3521.2 to 3806.5)	126.6 (121.8 to 131.6)	20.4
	Tackle 3	2183	175.9 (168.7 to 183.4)	3156.4 (3026.8 to 3291.7)	109.2 (104.7 to 113.8)	17.6
	Tackle 4	1769	142.5 (136.0 to 149.3)	2557.8 (2441.4 to 2679.9)	88.5 (84.4 to 92.7)	14.3
	Tackle 5	1135	91.4 (86.3 to 96.9)	1641.1 (1548.4 to 1739.4)	56.8 (53.5 to 60.1)	9.1
	Tackle 6	69	5.6 (4.4 to 7.0)	99.8 (78.8 to 126.3)	3.5 (2.7 to 4.4)	0.6
	Incomplete Tackle	1657	133.5 (127.2 to 140.1)	2395.9 (2283.3 to 2514.1)	82.9 (79.0 to 86.9)	13.3
Field Position						
Defence	In Goal	62	5.0 (3.9 to 6.4)	89.6 (69.9 to 115.0)	3.1 (2.4 to 4.0)	0.5
Defence	0-10	454	36.6 (33.4 to 40.1)	656.4 (598.8 to 719.7)	22.7 (20.7 to 24.9)	3.7
Defence	10-20	1205	97.1 (91.8 to 102.7)	1742.3 (1646.7 to 1843.5)	60.3 (56.9 to 63.7)	9.7
Defence	20-30	1673	134.8 (128.5 to 141.4)	2419.0 (2305.8 to 2537.8)	83.7 (79.7 to 87.8)	13.5
Defence	30-40	1680	135.4 (129.0 to 142.0)	2429.1 (2315.7 to 2548.1)	84.0 (80.1 to 88.1)	13.5
Defence	40-50	1477	119.0 (113.1 to 125.2)	2135.6 (2029.4 to 2247.4)	73.9 (70.2 to 77.7)	11.9
Attack	50-40	1146	92.3 (87.1 to 97.8)	1657.0 (1563.8 to 1755.8)	57.3 (54.1 to 60.7)	9.2
Attack	40-30	1014	81.7 (76.8 to 86.9)	1466.2 (1378.6 to 1559.2)	50.7 (47.7 to 53.9)	8.2
Attack	30-20	946	76.2 (71.5 to 81.2)	1367.8 (1283.4 to 1457.8)	47.3 (44.4 to 50.4)	7.6
Attack	20-10	1007	81.1 (76.3 to 86.3)	1456.0 (1368.8 to 1548.8)	50.4 (47.3 to 53.6)	8.1
Attack	10-0	1590	128.1 (122.0 to 134.6)	2299.0 (2188.7 to 2414.8)	79.5 (75.7 to 83.5)	12.8
Attack	In Goal	158	12.7 (10.9 to 14.9)	228.5 (195.5 to 267.0)	7.9 (6.8 to 9.2)	1.3

Table 4: Tackles by tackler and ball carrier at International level of participation for player position, player group and forwards and backs per 1000 tackle events and per match with 95% Confidence Intervals and percentages

	No.	1000 Tackled Events Rate (95% CI)	Rate expressed per 1000 match hours Rate (95% CI)	Match Rate (95% CI)	%
Player as Tackler					
1. Fullback	555	38.8 (35.7 to 42.2)	802.5 (738.4 to 872.1)	27.8 (25.5 to 30.2)	3.9
2. Wing	472	33.0 (30.2 to 36.2)	682.5 (623.6 to 746.9)	23.6 (21.6 to 25.8)	3.3
3. Centre	564	39.5 (36.3 to 42.9)	815.5 (750.9 to 885.7)	28.2 (26.0 to 30.6)	3.9
4. Centre	1099	76.9 (72.5 to 81.6)	1589.1 (1497.8 to 1685.9)	55.0 (51.8 to 58.3)	7.7
5. Wing	291	20.4 (18.2 to 22.8)	420.8 (375.1 to 472.0)	14.6 (13.0 to 16.3)	2.0
6. Stand Off	1127	78.9 (74.4 to 83.6)	1629.6 (1537.1 to 1727.5)	56.4 (53.2 to 59.7)	7.9
7. Half back	1279	89.5 (84.7 to 94.6)	1849.3 (1750.7 to 1953.5)	64.0 (60.5 to 67.6)	9.0
8. Prop	1380	96.6 (91.6 to 101.8)	1995.4 (1892.8 to 2103.5)	69.0 (65.5 to 72.7)	9.7
9. Hooker	1904	133.3 (127.4 to 139.4)	2753.0 (2632.1 to 2879.5)	95.2 (91.0 to 99.6)	13.3
10. Prop	1514	106.0 (100.8 to 111.4)	2189.1 (2081.6 to 2302.2)	75.7 (72.0 to 79.6)	10.6
11. second row	1134	79.4 (74.9 to 84.1)	1639.7 (1547.0 to 1737.9)	56.7 (53.5 to 60.1)	7.9
12. Second row	1495	104.6 (99.5 to 110.1)	2161.7 (2054.8 to 2274.1)	74.8 (71.1 to 78.6)	10.5
13. Loose Forward	1474	103.2 (98.0 to 108.6)	2131.3 (2025.2 to 2242.9)	73.7 (70.0 to 77.6)	10.3
Outside Backs	2981	208.6 (201.3 to 216.3)	4310.3 (4158.3 to 4467.8)	149.1 (143.8 to 154.5)	20.9
Adjustables	5784	404.8 (394.5 to 415.4)	8363.2 (8150.4 to 8581.6)	289.2 (281.8 to 296.8)	40.5
Hit Up Forwards	5523	386.5 (376.5 to 396.9)	7985.8 (7778.0 to 8199.2)	276.2 (269.0 to 283.5)	38.7
Forwards	8901	623.0 (610.2 to 636.0)	12870.2 (12605.5 to 13140.3)	445.1 (435.9 to 454.4)	62.3
Backs	5387	377.0 (367.1 to 387.2)	7789.2 (7583.9 to 8000.0)	269.4 (262.3 to 276.6)	37.7
Player as Ball Carrier					
1. Fullback	670	103.1 (95.5 to 111.2)	968.8 (898.1 to 1045.0)	33.5 (31.1 to 36.1)	10.3
2. Wing	583	89.7 (82.7 to 97.3)	843.0 (777.2 to 914.3)	29.2 (26.9 to 31.6)	9.0
3. Centre	486	74.8 (68.4 to 81.7)	702.7 (642.9 to 768.1)	24.3 (22.2 to 26.6)	7.5
4. Centre	568	87.4 (80.5 to 94.9)	821.3 (756.4 to 891.7)	28.4 (26.2 to 30.8)	8.7
5. Wing	520	80.0 (73.4 to 87.2)	751.9 (690.0 to 819.4)	26.0 (23.9 to 28.3)	8.0
6. Stand Off	378	58.1 (52.6 to 64.3)	546.6 (494.1 to 604.5)	18.9 (17.1 to 20.9)	5.8
7. Half back	341	52.5 (47.2 to 58.3)	493.1 (443.4 to 548.3)	17.1 (15.3 to 19.0)	5.2
8. Prop	574	88.3 (81.4 to 95.8)	830.0 (764.8 to 900.7)	28.7 (26.4 to 31.1)	8.8
9. Hooker	276	42.5 (37.7 to 47.8)	399.1 (354.7 to 449.0)	13.8 (12.3 to 15.5)	4.2
10. Prop	576	88.6 (81.7 to 96.1)	832.9 (767.5 to 903.7)	28.8 (26.5 to 31.3)	8.9
11. second row	595	91.5 (84.5 to 99.2)	860.3 (793.9 to 932.3)	29.8 (27.5 to 32.2)	9.2
12. Second row	471	72.5 (66.2 to 79.3)	681.0 (622.2 to 745.4)	23.6 (21.5 to 25.8)	7.2
13. Loose Forward	463	71.2 (65.0 to 78.0)	669.5 (611.2 to 733.3)	23.2 (21.1 to 25.4)	7.1
Outside Backs	2827	434.9 (419.1 to 451.2)	4087.6 (3939.7 to 4241.1)	141.4 (136.2 to 146.7)	43.5
Adjustables	1458	224.3 (213.1 to 236.1)	2108.2 (2002.7 to 2219.2)	72.9 (69.3 to 76.7)	22.4
Hit Up Forwards	2216	340.9 (327.0 to 355.4)	3204.2 (3073.5 to 3340.4)	110.8 (106.3 to 115.5)	34.1
Forwards	2955	238.1 (229.6 to 246.8)	4272.7 (4121.4 to 4429.6)	147.8 (142.5 to 153.2)	45.5
Backs	3546	285.7 (276.4 to 295.3)	5127.2 (4961.2 to 5298.8)	177.3 (171.6 to 183.2)	54.5

Table 5: Tackles at National Rugby League level of participation by number of tacklers, tackle height, degree of tackler position, tackle number and field position per 1000 tackle events and per match with 95% Confidence Intervals and percentages

		No.	Rate expressed per: 1000 Tackle Events Rate (95% CI)	1000 match hours Rate (95% CI)	Match Rate (95% CI)	%
Total		19523	1000.0 (986.1 to 1014.1)	18819.2 (18557.0 to 19085.0)	650.8 (641.7 to 660.0)	100.0
	First half	9748	499.31 (489.5 to 509.3)	9396.6 (9211.9 to 9585.0)	324.9 (318.6 to 331.5)	49.9
	Second Half	9775	500.69 (490.9 to 510.7)	9422.6 (9237.6 to 9611.3)	325.8 (319.4 to 332.4)	50.1
Number of Tacklers						
	1	3304	169.2 (163.6 to 175.1)	3184.9 (3078.1 to 3295.4)	110.1 (106.4 to 114.0)	16.9
	2	8958	458.8 (449.4 to 468.4)	8635.0 (8458.1 to 8815.7)	298.6 (292.5 to 304.8)	45.9
	3	6753	345.9 (337.7 to 354.2)	6509.5 (6356.1 to 6666.7)	225.1 (219.8 to 230.5)	34.6
	4 or more	508	26.0 (23.9 to 28.4)	489.7 (448.9 to 534.2)	16.9 (15.5 to 18.5)	2.6
Tackle Height						
	Head/Neck	1213	31.8 (30.1 to 33.6)	1169.3 (1105.3 to 1237.0)	40.4 (38.2 to 42.8)	3.2
	Shoulder	4582	120.1 (116.7 to 123.7)	4416.8 (4290.8 to 4546.6)	152.7 (148.4 to 157.2)	12.0
	Mid Torso	13828	362.5 (356.5 to 368.6)	13329.5 (13109.1 to 13553.5)	460.9 (453.3 to 468.7)	36.3
	Hip / Thigh	13536	354.9 (348.9 to 360.9)	13048.0 (12830.0 to 13269.7)	451.2 (443.7 to 458.9)	35.5
	Lower Legs	4985	130.7 (127.1 to 134.4)	4805.3 (4673.7 to 4940.5)	166.2 (161.6 to 170.8)	13.1
Degree of Tackler Position						
	300°-330°	6654	185.0 (180.6 to 189.5)	6414.1 (6261.8 to 6570.1)	221.8 (216.5 to 227.2)	18.5
	330°-360°	2788	77.5 (74.7 to 80.5)	2687.5 (2589.6 to 2789.1)	92.9 (89.5 to 96.4)	7.8
	000°-030°	3792	105.5 (102.1 to 108.9)	3655.3 (3540.8 to 3773.5)	126.4 (122.4 to 130.5)	10.5
	030°-060°	6581	183.0 (178.6 to 187.5)	6343.7 (6192.3 to 6498.9)	219.4 (214.1 to 224.7)	18.3
	060°-300°	16145	449.0 (442.1 to 456.0)	15562.9 (15324.7 to 15804.9)	538.2 (529.9 to 546.5)	44.9
Tackle No.						
	Tackle 0	307	15.7 (14.1 to 17.6)	295.9 (264.6 to 331.0)	10.2 (9.2 to 11.4)	1.6
	Tackle 1	4835	247.7 (240.8 to 254.7)	4660.7 (4531.2 to 4793.9)	161.2 (156.7 to 165.8)	24.8
	Tackle 2	4316	221.1 (214.6 to 227.8)	4160.4 (4038.1 to 4286.4)	143.9 (139.6 to 148.2)	22.1
	Tackle 3	3667	187.8 (181.8 to 194.0)	3534.8 (3422.2 to 3651.1)	122.2 (118.3 to 126.3)	18.8
	Tackle 4	2731	139.9 (134.7 to 145.2)	2632.5 (2535.6 to 2733.2)	91.0 (87.7 to 94.5)	14.0
	Tackle 5	1789	91.6 (87.5 to 96.0)	1724.5 (1646.4 to 1806.3)	59.6 (56.9 to 62.5)	9.2
	Tackle 6	91	4.7 (3.8 to 5.7)	87.7 (71.4 to 107.7)	3.0 (2.5 to 3.7)	0.5
	Incomplete Tackle	1787	91.5 (87.4 to 95.9)	1722.6 (1644.5 to 1804.3)	59.6 (56.9 to 62.4)	9.2
Field Position						
Defence	In Goal	128	6.6 (5.5 to 7.8)	123.4 (103.8 to 146.7)	4.3 (3.6 to 5.1)	0.7
Defence	0-10	638	32.7 (30.2 to 35.3)	615.0 (569.1 to 664.6)	21.3 (19.7 to 23.0)	3.3
Defence	10-20	2428	124.4 (119.5 to 129.4)	2340.5 (2249.2 to 2435.4)	80.9 (77.8 to 84.2)	12.4
Defence	20-30	2440	125.0 (120.1 to 130.0)	2352.0 (2260.5 to 2447.2)	81.3 (78.2 to 84.6)	12.5
Defence	30-40	3043	155.9 (150.4 to 161.5)	2933.3 (2830.9 to 3039.4)	101.4 (97.9 to 105.1)	15.6
Defence	40-50	2392	122.5 (117.7 to 127.5)	2305.8 (2215.2 to 2400.0)	79.7 (76.6 to 83.0)	12.3
Attack	50-40	1607	82.3 (78.4 to 86.4)	1549.1 (1475.1 to 1626.7)	53.6 (51.0 to 56.3)	8.2
Attack	40-30	1437	73.6 (69.9 to 77.5)	1385.2 (1315.4 to 1458.7)	47.9 (45.5 to 50.4)	7.4
Attack	30-20	1565	80.2 (76.3 to 84.2)	1508.6 (1435.7 to 1585.2)	52.2 (49.6 to 54.8)	8.0
Attack	20-10	1529	78.3 (74.5 to 82.3)	1473.9 (1401.8 to 1549.6)	51.0 (48.5 to 53.6)	7.8
Attack	10-0	2189	112.1 (107.5 to 116.9)	2110.1 (2023.5 to 2200.4)	73.0 (70.0 to 76.1)	11.2
Attack	In Goal	127	6.5 (5.5 to 7.7)	122.4 (102.9 to 145.7)	4.2 (3.6 to 5.0)	0.7

Table 6: Tackles by tackler and ball carrier at National Rugby League level of participation for player position, player group and forwards and backs per 1000 tackle events and per match with 95% Confidence Intervals and percentages

	No.	Rate expressed per 1000 Tackled Events Rate (95% CI)	1000 match hours Rate (95% CI)	Mean per Match Rate (95% CI)	%
Player as Tackler					
1. Fullback	287	14.1 (12.5 to 15.8)	276.7 (246.4 to 310.6)	9.6 (8.5 to 10.7)	1.4
2. Wing	460	22.5 (20.6 to 24.7)	443.4 (404.7 to 485.8)	15.3 (14.0 to 16.8)	2.3
3. Centre	1095	53.7 (50.6 to 56.9)	1055.5 (994.8 to 1119.9)	36.5 (34.4 to 38.7)	5.4
4. Centre	1241	60.8 (57.5 to 64.3)	1196.3 (1131.5 to 1264.7)	41.4 (39.1 to 43.7)	6.1
5. Wing	396	19.4 (17.6 to 21.4)	381.7 (345.9 to 421.2)	13.2 (12.0 to 14.6)	1.9
6. Stand Off	2347	115.0 (110.5 to 119.8)	2262.4 (2172.7 to 2355.8)	78.2 (75.1 to 81.5)	11.5
7. Half back	1184	58.0 (54.8 to 61.4)	1141.3 (1078.1 to 1208.2)	39.5 (37.3 to 41.8)	5.8
8. Prop	1659	81.3 (77.5 to 85.3)	1599.2 (1524.1 to 1678.0)	55.3 (52.7 to 58.0)	8.1
9. Hooker	3119	152.9 (147.6 to 158.3)	3006.6 (2902.9 to 3113.9)	104.0 (100.4 to 107.7)	15.3
10. Prop	1567	76.8 (73.1 to 80.7)	1510.5 (1437.5 to 1587.2)	52.2 (49.7 to 54.9)	7.7
11. Second row	1663	81.5 (77.7 to 85.5)	1603.0 (1527.8 to 1682.0)	55.4 (52.8 to 58.2)	8.2
12. Second row	2833	138.8 (133.8 to 144.1)	2730.9 (2632.1 to 2833.3)	94.4 (91.0 to 98.0)	13.9
13. Loose Forward	2553	125.1 (120.4 to 130.1)	2461.0 (2367.3 to 2558.3)	85.1 (81.9 to 88.5)	12.5
Outside Backs	3479	170.5 (164.9 to 176.3)	3353.6 (3244.0 to 3466.9)	116.0 (112.2 to 119.9)	17.1
Adjustables	9203	451.0 (441.9 to 460.3)	8871.2 (8691.8 to 9054.3)	306.8 (300.6 to 313.1)	45.1
Hit Up Forwards	7722	378.5 (370.1 to 387.0)	7443.6 (7279.4 to 7611.5)	257.4 (251.7 to 263.2)	37.8
Forwards	13394	656.4 (645.4 to 667.7)	12911.1 (12694.3 to 13131.6)	446.5 (439.0 to 454.1)	65.6
Backs	7010	343.6 (335.6 to 351.7)	6757.3 (6600.9 to 6917.3)	233.7 (228.3 to 239.2)	34.4
Player as Ball Carrier					
1. Fullback	924	97.2 (91.1 to 103.7)	890.7 (835.1 to 950.0)	30.8 (28.9 to 32.9)	9.7
2. Wing	827	87.0 (81.3 to 93.1)	797.2 (744.7 to 853.4)	27.6 (25.8 to 29.5)	8.7
3. Centre	740	77.8 (72.4 to 83.7)	713.3 (663.7 to 766.6)	24.7 (23.0 to 26.5)	7.8
4. Centre	801	84.3 (78.6 to 90.3)	772.1 (720.5 to 827.5)	26.7 (24.9 to 28.6)	8.4
5. Wing	839	88.3 (82.5 to 94.4)	808.8 (755.8 to 865.4)	28.0 (26.1 to 29.9)	8.8
6. Stand Off	545	57.3 (52.7 to 62.4)	525.4 (483.0 to 571.4)	18.2 (16.7 to 19.8)	5.7
7. Half back	346	36.4 (32.8 to 40.4)	333.5 (300.2 to 370.6)	11.5 (10.4 to 12.8)	3.6
8. Prop	806	84.8 (79.1 to 90.8)	776.9 (725.1 to 832.5)	26.9 (25.1 to 28.8)	8.5
9. Hooker	479	50.4 (46.1 to 55.1)	461.7 (422.2 to 505.0)	16.0 (14.6 to 17.5)	5.0
10. Prop	727	76.5 (71.1 to 82.2)	700.8 (651.7 to 753.6)	24.2 (22.5 to 26.1)	7.6
11. second row	1110	116.8 (110.1 to 123.8)	1070.0 (1008.9 to 1134.8)	37.0 (34.9 to 39.2)	11.7
12. Second row	839	88.3 (82.5 to 94.4)	808.8 (755.8 to 865.4)	28.0 (26.1 to 29.9)	8.8
13. Loose Forward	523	55.0 (50.5 to 59.9)	504.1 (462.7 to 549.3)	17.4 (16.0 to 19.0)	5.5
Outside Backs	4131	434.6 (421.5 to 448.0)	3 982.1 (3862.5 to 4105.4)	137.7 (133.6 to 142.0)	43.5
Adjustables	1893	199.1 (190.4 to 208.3)	1824.8 (1744.4 to 1908.8)	63.1 (60.3 to 66.0)	19.9
Hit Up Forwards	3482	366.3 (354.3 to 378.7)	3356.5 (3246.8 to 3469.8)	116.1 (112.3 to 120.0)	36.6
Forwards	4484	471.7 (458.1 to 485.7)	4322.3 (4197.7 to 4450.7)	149.5 (145.2 to 153.9)	47.2
Backs	5022	528.3 (513.9 to 543.1)	4840.9 (4708.9 to 4976.7)	167.4 (162.8 to 172.10	52.8

Table 7: Tackles at National Youth Competition level of participation by number of tacklers, tackle height, degree of tackler position, tackle number and field position per 1000 tackle events and per match with 95% Confidence Intervals and percentages

		No.	Rate expressed per: 1000 Tackled Events Rate (95% CI)	1000 Match hours Rate (95% CI)	Mean per match Rate (95% CI)	%
Total		18084	1000.0 (985.5 to 1014.7)	17432.0 (17179.8 to 17688.0)	602.8 (594.1 to 611.7)	100.0
	First half	9158	506.4 (496.1 to 516.9)	8827.8 (8648.9 to 9010.5)	305.3 (299.1 to 311.6)	50.6
	Second Half	8926	493.6 (483.5 to 503.9)	8604.2 (8427.5 to 8784.6)	297.5 (291.4 to 303.8)	49.4
Number of Tacklers						
	1	3302	182.6 (176.5 to 188.9)	3183.0 (3076.2 to 3293.4)	110.1 (106.4 to 113.9)	18.3
	2	8370	462.8 (453.0 to 472.9)	8068.2 (7897.2 to 8243.0)	279.0 (273.1 to 285.0)	46.3
	3	5555	307.2 (299.2 to 315.4)	5354.7 (5215.8 to 5497.4)	185.2 (180.4 to 190.1)	30.7
	4 or more	857	47.4 (44.3 to 50.7)	826.1 (772.6 to 883.3)	28.6 (26.7 to 30.5)	4.7
Direction						
	Left Front	5147	136.7 (133.0 to 140.5)	1421.8 (1351.1 to 1496.3)	171.6 (166.9 to 176.3)	13.7
	Front	5466	145.2 (141.4 to 149.1)	3859.6 (3741.9 to 3981.1)	182.2 (177.4 to 187.1)	14.5
	Right Front	6543	173.8 (169.6 to 178.0)	11704.3 (11497.9 to 11914.3)	218.1 (212.9 to 223.4)	17.4
	Side	12998	345.2 (339.3 to 351.2)	12040.7 (11831.4 to 12253.7)	433.3 (425.9 to 440.8)	34.5
	Behind	7503	199.2 (194.8 to 203.8)	4074.6 (3953.6 to 4199.3)	250.1 (244.5 to 255.8)	19.9
Degree of Tackler Position						
	300°-330°	5061	157.5 (153.3 to 161.9)	4878.5 (4746.0 to 5014.8)	168.7 (164.1 to 173.4)	15.8
	330°-360°	2542	79.1 (76.1 to 82.3)	2450.4 (2356.9 to 2547.5)	84.7 (81.5 to 88.1)	7.9
	000°-030°	3460	107.7 (104.2 to 111.4)	3335.3 (3226.0 to 3448.3)	115.3 (111.6 to 119.2)	10.8
	030°-060°	6543	203.7 (198.8 to 208.7)	6307.1 (6156.1 to 6461.8)	218.1 (212.9 to 223.4)	20.4
	060°-300°	14519	452.0 (444.7 to 459.4)	13995.6 (13769.8 to 14225.1)	484.0 (476.2 to 491.9)	45.2
Tackle No.						
	Tackle 0	404	22.3 (20.3 to 24.6)	389.4 (353.3 to 429.3)	13.5 (12.2 to 14.8)	2.2
	Tackle 1	4436	245.3 (238.2 to 252.6)	4276.1 (4152.1 to 4403.8)	147.9 (143.6 to 152.3)	24.5
	Tackle 2	3534	195.4 (189.1 to 202.0)	3406.6 (3296.1 to 3520.8)	117.8 (114.0 to 121.7)	19.5
	Tackle 3	2982	164.9 (159.1 to 170.9)	2874.5 (2773.2 to 2979.5)	99.4 (95.9 to 103.0)	16.5
	Tackle 4	2374	131.3 (126.1 to 136.7)	2288.4 (2198.2 to 2382.3)	79.1 (76.0 to 82.4)	13.1
	Tackle 5	1536	84.9 (80.8 to 89.3)	1480.6 (1408.4 to 1556.6)	51.2 (48.7 to 53.8)	8.5
	Tackle 6	57	3.2 (2.4 to 4.1)	54.9 (42.4 to 71.2)	1.9 (1.5 to 2.5)	0.3
	Incomplete Tackle	2761	152.7 (147.1 to 158.5)	2661.5 (2564.0 to 2762.6)	92.0 (88.7 to 95.5)	15.3
Field Position						
Defence	In Goal	206	11.4 (9.9 to 13.1)	198.6 (173.2 to 227.6)	6.9 (6.0 to 7.9)	1.1
Defence	0-10	528	29.2 (26.8 to 31.8)	509.0 (467.4 to 554.3)	17.6 (16.2 to 19.2)	2.9
Defence	10-20	1768	97.8 (93.3 to 102.4)	1704.3 (1626.6 to 1785.6)	58.9 (56.2 to 61.7)	9.8
Defence	20-30	2400	132.7 (127.5 to 138.1)	2313.5 (2222.7 to 2407.9)	80.0 (76.9 to 83.3)	13.3
Defence	30-40	2361	130.6 (125.4 to 135.9)	2275.9 (2185.9 to 2369.6)	78.7 (75.6 to 81.9)	13.1
Defence	40-50	2287	126.5 (121.4 to 131.8)	2204.5 (2116.0 to 2296.8)	76.2 (73.2 to 79.4)	12.6
Attack	50-40	1967	108.8 (104.1 to 113.7)	1896.1 (1814.1 to 1981.8)	65.6 (62.7 to 68.5)	10.9
Attack	40-30	1538	85.0 (80.9 to 89.4)	1482.6 (1410.3 to 1558.5)	51.3 (48.8 to 53.9)	8.5
Attack	30-20	1445	79.9 (75.9 to 84.1)	1392.9 (1322.9 to 1466.6)	48.2 (45.7 to 50.7)	8.0
Attack	20-10	1218	67.4 (63.7 to 71.2)	1174.1 (1110.0 to 1241.9)	40.6 (38.4 to 42.9)	6.7
Attack	10-0	2187	120.9 (116.0 to 126.1)	2108.2 (2021.6 to 2198.4)	72.9 (69.9 to 76.0)	12.1
Attack	In Goal	179	9.9 (8.5 to 11.5)	172.5 (149.0 to 199.8)	6.0 (5.2 to 6.9)	1.0

Table 8: Tackles by tackler and ball carrier at National Youth Competition level of participation for player position, player group and forwards and backs per 1000 tackle events and per match with 95% Confidence Intervals and percentages

	No.	Rate expressed per 1000 Tackled Events Rate (95% CI)	1000 Match hours Rate (95% CI)	Mean per match Rate (95% CI)	%
Player as Tackler					
1. Fullback	765	37.2 (34.7 to 39.9)	737.4 (687.0 to 791.6)	25.5 (23.8 to 27.4)	3.7
2. Wing	360	17.5 (15.8 to 19.4)	347.0 (313.0 to 384.8)	12.0 (10.8 to 13.3)	1.8
3. Centre	1020	49.6 (46.6 to 52.7)	983.2 (924.7 to 1045.5)	34.0 (32.0 to 36.2)	5.0
4. Centre	1555	75.6 (71.9 to 79.5)	1498.9 (1426.3 to 1575.3)	51.8 (49.3 to 54.5)	7.6
5. Wing	240	11.7 (10.3 to 13.2)	231.3 (203.9 to 262.5)	8.0 (7.0 to 9.1)	1.2
6. Stand Off	2417	117.5 (112.9 to 122.3)	2329.9 (2238.8 to 2424.6)	80.6 (77.4 to 83.8)	11.8
7. Half back	1395	67.8 (64.4 to 71.5)	1344.7 (1276.0 to 1417.2)	46.5 (44.1 to 49.0)	6.8
8. Prop	1785	86.8 (82.9 to 90.9)	1720.6 (1642.6 to 1802.4)	59.5 (56.8 to 62.3)	8.7
9. Hooker	3115	151.5 (146.2 to 156.9)	3002.7 (2899.1 to 3110.0)	103.8 (100.3 to 107.5)	15.1
10. Prop	1905	92.6 (88.6 to 96.9)	1836.3 (1755.7 to 1920.7)	63.5 (60.7 to 66.4)	9.3
11. second row	1200	58.4 (55.1 to 61.7)	1156.7 (1093.1 to 1224.1)	40.0 (37.8 to 42.3)	5.8
12. Second row	2326	113.1 (108.6 to 117.8)	2242.1 (2152.9 to 2335.1)	77.5 (74.4 to 80.7)	11.3
13. Loose Forward	2482	120.7 (116.0 to 125.5)	2392.5 (2300.2 to 2488.5)	82.7 (79.5 to 86.1)	12.1
Outside Backs	3940	191.6 (185.7 to 197.7)	3798.0 (3681.2 to 3918.4)	131.3 (127.3 to 135.5)	19.2
Adjustables	9409	457.5 (448.4 to 466.9)	9069.8 (8888.4 to 9254.9)	313.6 (307.4 to 320.0)	45.8
Hit Up Forwards	7216	350.9 (342.9 to 359.1)	6955.9 (6797.2 to 7118.2)	240.5 (235.0 to 246.1)	35.1
Forwards	12813	623.0 (612.4 to 633.9)	12351.1 (12139.0 to 12566.8)	427.1 (419.8 to 434.6)	62.3
Backs	7752	377.0 (368.7 to 385.4)	7472.5 (7308.0 to 7640.7)	258.4 (252.7 to 264.2)	37.7
Player as Ball Carrier					
1. Fullback	1055	112.5 (105.9 to 119.5)	1017.0 (957.4 to 1080.2)	35.2 (33.1 to 37.4)	11.3
2. Wing	770	82.1 (76.5 to 88.1)	742.2 (691.6 to 796.6)	25.7 (23.9 to 27.5)	8.2
3. Centre	770	82.1 (76.5 to 88.1)	742.2 (691.6 to 796.6)	25.7 (23.9 to 27.5)	8.2
4. Centre	680	72.5 (67.3 to 78.2)	655.5 (608.0 to 706.7)	22.7 (21.0 to 24.4)	7.3
5. Wing	923	98.5 (92.3 to 105.0)	889.7 (834.1 to 949.0)	30.8 (28.8 to 32.8)	9.8
6. Stand Off	427	45.5 (41.4 to 50.1)	411.6 (374.4 to 452.6)	14.2 (12.9 to 15.6)	4.6
7. Half back	525	56.0 (51.4 to 61.0)	506.1 (464.6 to 551.3)	17.5 (16.1 to 19.1)	5.6
8. Prop	985	105.1 (98.7 to 111.8)	949.5 (892.0 to 1010.7)	32.8 (30.8 to 34.9)	10.5
9. Hooker	465	49.6 (45.3 to 54.3)	448.2 (409.3 to 490.9)	15.5 (14.2 to 17.0)	5.0
10. Prop	805	85.9 (80.1 to 92.0)	776.0 (724.2 to 831.5)	26.8 (25.0 to 28.8)	8.6
11. second row	620	66.1 (61.1 to 71.5)	597.6 (552.4 to 646.6)	20.7 (19.1 to 22.4)	6.6
12. Second row	730	77.9 (72.4 to 83.7)	703.7 (654.4 to 756.6)	24.3 (22.6 to 26.2)	7.8
13. Loose Forward	620	66.1 (61.1 to 71.5)	597.6 (552.4 to 646.6)	20.7 (19.1 to 22.4)	6.6
Outside Backs	4198	447.8 (434.4 to 461.5)	4046.7 (3926.1 to 4170.9)	139.9 (135.8 to 144.2)	44.8
Adjustables	2037	217.3 (208.0 to 226.9)	1963.6 (1880.1 to 2050.7)	67.9 (65.0 to 70.9)	21.7
Hit Up Forwards	3140	334.9 (323.4 to 346.9)	3026.8 (2922.8 to 3134.5)	104.7 (101.1 to 108.4)	33.5
Forwards	4225	450.7 (437.3 to 464.5)	4072.7 (3951.7 to 4197.4)	140.8 (136.7 to 145.1)	45.1
Backs	5150	549.3 (534.5 to 564.5)	4964.3 (4830.6 to 5101.8)	171.7 (167.0 to 176.4)	54.9

Appendix 6: Supplemental data for Chapter 10

Nature of tackles that result in injury in professional rugby league

Tackle Injury data

Table 1: Total tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

			Injury rate per 1000		
			Tackle events	Match hours	
		No.	Rate (95% CI)	Rate (95% CI)	%
Total		249	7.9 (6.9 to 8.9)	300.0 (265.0 to 339.7)	100.0
Number of Tacklers					
	1	87	2.7 (2.2 to 3.4)	104.8 (85.0 to 129.3)	34.9
	2	107	3.4 (2.8 to 4.1)	128.9 (106.7 to 155.8)	43.0
	3	46	1.5 (1.1 to 1.9)	55.4 (41.5 to 74.0)	18.5
	4 or more	9	0.3 (0.1 to 0.5)	10.8 (5.6 to 20.8)	3.6
Tackle Height					
	Head/Neck	74	2.3 (1.9 to 2.9)	89.2 (71.0 to 112.0)	19.6
	Shoulder	125	3.9 (3.3 to 4.7)	150.6 (126.4 to 179.5)	33.2
	Mid Torso	105	3.3 (2.7 to 4.0)	126.5 (104.5 to 153.2)	27.9
	Hip / Thigh	59	1.9 (1.4 to 2.4)	71.1 (55.1 to91.8)	15.6
	Lower Legs	14	0.4 (0.3 to 0.7)	16.9 (10.0 to 28.5)	3.7
Degree of Tackler Position					
	300-330	68	2.1 (1.7 to 2.7)	81.9 (64.6 to 103.9)	19.2
	330-360	33	1.0 (0.7 to 1.5)	39.8 (28.3 to 55.9)	9.3
	0-30	38	1.2 (0.9 to 1.6)	45.8 (33.3 to 62.9)	10.7
	30-60	66	2.1 (1.6 to 2.7)	79.5 (62.5 to 101.2)	18.6
	60-300	149	4.7 (4.0 to 5.5)	179.5 (152.9 to 210.8)	42.1
Match Time					
	1st Quarter	49	1.5 (1.2 to 2.0)	236.2 (178.5 to 312.5)	19.7
	2nd Quarter	49	1.5 (1.2 to 2.0)	236.2 (178.5 to 312.5)	19.7
	3rd Quarter	77	2.4 (1.9 to 3.0)	371.1 (296.8 to 464.0)	30.9
	4th Quarter	74	2.3 (1.9 to 2.9)	356.7 (284.0 to 447.9)	29.7
Field Position					
Defence	In Goal	2	0.1 (0.0 to 0.3)	2.4 (0.6 to 9.6)	0.8
	0-10	14	0.4 (0.3 to 0.7)	16.9 (10.0 to 28.5)	5.6
	10-20	18	0.6 (0.4 to 0.9)	21.7 (13.7 to 34.4)	7.2
	20-30	29	0.9 (0.6 to 1.3)	34.9 (24.3 to 50.3)	11.6
	30-40	32	1.0 (0.7 to 1.4)	38.6 (27.3 to 54.5)	12.9
	40-50	33	1.0 (0.7 to 1.5)	39.8 (28.3 to 55.9)	13.3
Attack	50-40	24	0.8 (0.5 to 1.1)	28.9 (19.4 to 43.1)	9.6
	40-30	30	0.9 (0.7 to 1.4)	36.1 (25.3 to 51.7)	12.0
	30-20	22	0.7 (0.5 to 1.1)	26.5 (17.5 to 40.3)	8.8
	20-10	21	0.7 (0.4 to 1.0)	25.3 (16.5 to 38.8)	8.4
	10-0	21	0.7 (0.4 to 1.0)	25.3 (16.5 to 38.8)	8.4
	In Goal	3	0.1 (0.0 to 0.3)	3.6 (1.2 to 11.2)	1.2
Injury Severity					
	Transient (0 – 4 days)	201	6.3 (5.5 to 7.3)	242.2 (210.9 to 278.1)	80.7
	Mild (4 – 7 days)	30	0.9 (0.7 to 1.4)	36.1 (25.3 to 51.7)	12.0
	Moderate (7 – 21 days)	4	0.1 (0.0 to 0.3)	4.8 (1.8 to 12.8)	1.6
	Major (21 days +)	14	0.4 (0.3 to 0.7)	16.9 (10.0 to 28.5)	5.6
Tackle No.					
	Tackle 0	2	0.1 (0.0 to 0.3)	2.4 (0.6 to 9.6)	0.8
	Tackle 1	51	1.6 (1.2 to 2.1)	61.5 (46.7 to 80.9)	20.5
	Tackle 2	58	1.8 (1.4 to 2.4)	69.9 (54.0 to 90.4)	23.3
	Tackle 3	56	1.8 (1.4 to 2.3)	67.5 (51.9 to 87.7)	22.5
	Tackle 4	46	1.5 (1.1 to 1.9)	55.4 (41.5 to 74.0)	18.5
	Tackle 5	32	1.0 (0.7 to 1.4)	38.6 (27.3 to 54.5)	12.9
	Tackle 6	2	0.1 (0.0 to 0.3)	2.4 (0.6 to 9.6)	0.8
	Incomplete Tackle	2	0.1 (0.0 to 0.3)	2.4 (0.6 to 9.6)	0.8

CI: Confidence Interval

Table 2: Total tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		Injury rate per 1000		
		Tackle events	Match hours	
	No.	Rate (95% CI)	Rate (95% CI)	%
Position				
1. Fullback	18	7.4 (4.7 to 11.7)	282.0 (177.6 to 447.5)	7.2
2. Wing	8	3.3 (1.6 to 6.6)	125.3 (62.7 to 250.6)	3.2
3. Centre	20	8.2 (5.3 to 12.7)	313.3 (202.1 to 485.6)	8.0
4. Centre	15	6.2 (3.7 to 10.2)	235.0 (141.6 to 389.7)	6.0
5. Wing	13	5.3 (3.1 to 9.2)	203.6 (118.2 to 350.7)	5.2
6. Stand Off	13	5.3 (3.1 to 9.2)	203.6 (118.2 to 350.7)	5.2
7. Half back	20	8.2 (5.3 to 12.7)	313.3 (202.1 to 485.6)	8.0
8. Prop	31	12.7 (9.0 to 18.1)	485.6 (341.5 to 690.5)	12.4
9. Hooker	26	10.7 (7.3 to 15.7)	407.3 (277.3 to 598.2)	10.4
10. Prop	17	7.0 (4.3 to 11.2)	266.3 (165.5 to 428.4)	6.8
11. second row	22	9.0 (5.9 to 13.7)	344.6 (226.9 to 523.4)	8.8
12. Second row	30	12.3 (8.6 to 17.6)	469.9 (328.6 to 672.1)	12.0
13. Loose Forward	16	6.6 (4.0 to 10.7)	250.6 (153.5 to 409.1)	6.4
Forwards	142	9.7 (8.2 to 11.5)	370.7 (314.5 to 437.0)	57.0
Backs	107	6.3 (5.2 to 7.6)	239.4 (198.1 to 289.4)	43.0
Injury Type				
Abrasions	2	0.1 (0.0 to 0.3)	2.4 (0.6 to 9.6)	0.8
Sprains	50	1.6 (1.2 to 2.1)	60.2 (45.7 to 79.5)	20.1
Strains	60	1.9 (1.5 to 2.4)	72.3 (56.1 to 93.1)	24.1
Lacerations	7	0.2 (0.1 to 0.5)	8.4 (4.0 to 17.7)	2.8
Bruise	87	2.7 (2.2 to 3.4)	104.8 (85.0 to 129.3)	34.9
Inflammation	1	0.0 (0.0 to 0.2)	1.2 (0.2 to 8.6)	0.4
Fracture	11	0.3 (0.2 to 0.6)	13.3 (7.3 to 23.9)	4.4
Dislocation	8	0.3 (0.1 to 0.5)	9.6 (4.8 to 19.3)	3.2
Cramp	1	0.0 (0.0 to 0.2)	1.2 (0.2 to 8.6)	0.4
Concussion	18	0.6 (0.4 to 0.9)	21.7 (13.7 to 34.4)	7.2
Other	4	0.1 (0.0 to 0.3)	4.8 (1.8 to 12.8)	1.6
Injury Site				
Head	27	0.9 (0.6 to 1.2)	32.5 (22.3 to 47.4)	10.8
Eye	1	0.0 (0.0 to 0.2)	1.2 (0.2 to 8.6)	0.4
Nose	1	0.0 (0.0 to 0.2)	1.2 (0.2 to 8.6)	0.4
Mouth	3	0.1 (0.0 to 0.3)	3.6 (1.2 to 11.2)	1.2
Neck	7	0.2 (0.1 to 0.5)	8.4 (4.0 to 17.7)	2.8
Shoulder	28	0.9 (0.6 to 1.3)	33.7 (23.3 to 48.9)	11.2
U Arm	10	0.3 (0.2 to 0.6)	12.0 (6.5 to 22.4)	4.0
Elbow	12	0.4 (0.2 to 0.7)	14.5 (8.2 to 25.5)	4.8
L Arm	3	0.1 (0.0 to 0.3)	3.6 (1.2 to 11.2)	1.2
Wrist	6	0.2 (0.1 to 0.4)	7.2 (3.2 to 16.1)	2.4
Hand	7	0.2 (0.1 to 0.5)	8.4 (4.0 to 17.7)	2.8
Finger	5	0.2 (0.1 to 0.4)	6.0 (2.5 to 14.5)	2.0
Chest	19	0.6 (0.4 to 0.9)	22.9 (14.6 to 35.9)	7.6
Back	4	0.1 (0.0 to 0.3)	4.8 (1.8 to 12.8)	1.6
Groin	20	0.6 (0.4 to 1.0)	24.1 (15.5 to 37.4)	8.0
Hamstring	3	0.1 (0.0 to 0.3)	3.6 (1.2 to 11.2)	1.2
Quadriceps	25	0.8 (0.5 to 1.2)	30.1 (20.4 to 44.6)	10.0
Knee	30	0.9 (0.7 to 1.4)	36.1 (25.3 to 51.7)	12.0
Lower Leg	22	0.7 (0.5 to 1.1)	26.5 (17.5 to 40.3)	8.8
Ankle	15	0.5 (0.3 to 0.8)	18.1 (10.9 to 30.0)	6.0
Toe	1	0.0 (0.0 to 0.2)	1.2 (0.2 to 8.6)	0.4
Injury Region				
Head/Neck	39	1.2 (0.9 to 1.7)	47.0 (34.3 to 64.3)	15.7
Upper Limb	71	2.2 (1.8 to 2.8)	85.6 (67.8 to 108.0)	28.5
Chest/Back	23	0.7 (0.5 to 1.1)	27.7 (18.4 to 41.7)	9.2
Lower Limb	116	3.7 (3.1 to 4.4)	139.8 (116.5 to 167.7)	46.6

Table 3: Ball player tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

			Injury rate per 1000		
			Tackle events	Match hours	
		No.	Rate (95% CI)	Rate (95% CI)	%
Total		132	8.4 (7.1 to 10.0)	159.1 (134.1 to 188.6)	53.0
Number of Tacklers					
	1	30	1.9 (1.3 to 2.7)	36.1 (25.3 to 51.7)	22.7
	2	59	3.8 (2.9 to 4.9)	71.1 (55.1 to 91.8)	44.7
	3	37	2.4 (1.7 to 3.3)	44.6 (32.3 to 61.5)	28.0
	4 or more	6	0.4 (0.2 to 0.9)	7.2 (3.2 to 16.1)	4.5
Tackle Height					
	Head/Neck	63	4.0 (3.1 to 5.1)	75.9 (59.3 to 97.2)	24.2
	Shoulder	81	5.2 (4.2 to 6.4)	97.6 (78.5 to 121.3)	31.2
	Mid Torso	71	4.5 (3.6 to 5.7)	85.6 (67.8 to 108.0)	27.3
	Hip / Thigh	38	2.4 (1.8 to 3.3)	45.8 (33.3 to 62.9)	14.6
	Lower Legs	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	2.7
Degree of Tackler Position					
	300-330	49	3.1 (2.4 to 4.1)	59.0 (44.6 to 78.1)	20.7
	330-360	20	1.3 (0.8 to 2.0)	24.1 (15.5 to 37.4)	8.4
	0-30	25	1.6 (1.1 to 2.4)	30.1 (20.4 to 44.6)	10.5
	30-60	44	2.8 (2.1 to 3.8)	53.0 (39.5 to 71.2)	18.6
	60-300	99	6.3 (5.2 to 7.7)	119.3 (98.0 to 145.3)	41.8
Match Time					
	1st Quarter	33	2.1 (1.5 to 3.0)	159.1 (113.1 to 223.7)	25.0
	2nd Quarter	26	1.7 (1.1 to 2.4)	125.3 (85.3 to 184.0)	19.7
	3rd Quarter	35	2.2 (1.6 to 3.1)	168.7 (121.1 to 234.9)	26.5
	4th Quarter	38	2.4 (1.8 to 3.3)	183.2 (133.3 to 251.7)	28.8
Field Position					
Defence	In Goal	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Defence	0-10	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.0
Defence	10-20	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	7.6
Defence	20-30	22	1.4 (0.9 to 2.1)	26.5 (17.5 to 40.3)	16.7
Defence	30-40	20	1.3 (0.8 to 2.0)	24.1 (15.5 to 37.4)	15.2
Defence	40-50	20	1.3 (0.8 to 2.0)	24.1 (15.5 to 37.4)	15.2
Attack	50-40	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	5.3
Attack	40-30	12	0.8 (0.4 to 1.3)	14.5 (8.2 to 25.5)	9.1
Attack	30-20	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	9.8
Attack	20-10	9	0.6 (0.3 to 1.1)	10.8 (5.6 to 20.8)	6.8
Attack	10-0	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	9.8
Attack	In Goal	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Injury Severity					
	Transient (0 - 4 days)	100	6.4 (5.2 to 7.8)	120.5 (99.0 to 146.6)	75.8
	Mild (4 - 7 days)	20	1.3 (0.8 to 2.0)	24.1 (15.5 to 37.4)	15.2
	Moderate (7 - 21 days)	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
	Major (21 days +)	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	7.6
Tackle No.					
	Tackle 0	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
	Tackle 1	29	1.8 (1.3 to 2.7)	34.9 (24.3 to 50.3)	22.0
	Tackle 2	31	2.0 (1.4 to 2.8)	37.4 (26.3 to 53.1)	23.5
	Tackle 3	28	1.8 (1.2 to 2.6)	33.7 (23.3 to 48.9)	21.2
	Tackle 4	22	1.4 (0.9 to 2.1)	26.5 (17.5 to 40.3)	16.7
	Tackle 5	16	1.0 (0.6 to 1.7)	19.3 (11.8 to 31.5)	12.1
	Tackle 6	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
	Incomplete Tackle	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5

Table 4: Ball player tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		Injury rate per 1000		
		Tackle events	Match hours	
	No.	Rate (95% CI)	Rate (95% CI)	%
Player Position.				
1. Fullback	13	10.8 (6.3 to 18.5)	203.6 (118.2 to 350.7)	9.8
2. Wing	7	5.8 (2.8 to 12.2)	109.6 (52.3 to 230.0)	5.3
3. Centre	13	10.8 (6.3 to 18.5)	203.6 (118.2 to 350.7)	9.8
4. Centre	10	8.3 (4.5 to 15.4)	156.6 (84.3 to 291.1)	7.6
5. Wing	9	7.5 (3.9 to 14.3)	141.0 (73.4 to 270.9)	6.8
6. Stand Off	7	5.8 (2.8 to 12.2)	109.6 (52.3 to 230.0)	5.3
7. Half back	6	5.0 (2.2 to 11.1)	94.0 (42.2 to 209.2)	4.5
8. Prop	17	14.1 (8.8 to 22.7)	266.3 (165.5 to 428.4)	12.9
9. Hooker	4	3.3 (1.2 to 8.8)	62.7 (23.5 to 166.9)	3.0
10. Prop	9	7.5 (3.9 to 14.3)	141.0 (73.4 to 270.9)	6.8
11. second row	14	11.6 (6.9 to 19.6)	219.3 (129.9 to 370.3)	10.6
12. Second row	13	10.8 (6.3 to 18.5)	203.6 (118.2 to 350.7)	9.8
13. Loose Forward	10	8.3 (4.5 to 15.4)	156.6 (84.3 to 291.1)	7.6
Forwards	67	9.3 (7.3 to 11.8)	174.9 (137.7 to 222.2)	50.8
Backs	65	7.7 (6.0 to 9.8)	145.5 (114.1 to 185.5)	49.2
Injury Type				
Sprains	28	1.8 (1.2 to 2.6)	33.7 (23.3 to 48.9)	21.2
Strains	29	1.8 (1.3 to 2.7)	34.9 (24.3 to 50.3)	22.0
Lacerations	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.3
Bruise	50	3.2 (2.4 to 4.2)	60.2 (45.7 to 79.5)	37.9
Fracture	8	0.5 (0.3 to 1.0)	9.6 (4.8 to 19.3)	6.1
Dislocation	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
Concussion	11	0.7 (0.4 to 1.3)	13.3 (7.3 to 23.9)	8.3
Other	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Injury Site				
Head	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	9.8
Eye	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Nose	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Mouth	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.3
Neck	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.3
Shoulder	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	7.6
U Arm	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.3
Wrist	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Hand	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Chest	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	7.6
Back	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
Groin	16	1.0 (0.6 to 1.7)	19.3 (11.8 to 31.5)	12.1
Hamstring	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.5
Quadriceps	21	1.3 (0.9 to 2.1)	25.3 (16.5 to 38.8)	15.9
Knee	20	1.3 (0.8 to 2.0)	24.1 (15.5 to 37.4)	15.2
Lower Leg	14	0.9 (0.5 to 1.5)	16.9 (10.0 to 28.5)	10.6
Ankle	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	7.6
Toe	1	0.1 (0.0 to 0.5)	1.2 (0.2 to 8.6)	0.8
Injury Region				
Head/Neck	21	1.3 (0.9 to 2.1)	25.3 (16.5 to 38.8)	15.9
Upper Limb	15	1.0 (0.6 to 1.6)	18.1 (10.9 to 30.0)	11.4
Chest/Back	12	0.8 (0.4 to 1.3)	14.5 (8.2 to 25.5)	9.1
Lower Limb	84	5.4 (4.3 to 6.6)	101.2 (81.7 to 125.3)	63.6

Table 5: Tackler tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

			Injury rate per 1000		
			Tackle events	Match hours	
		No.	Rate (95% CI)	Rate (95% CI)	%
Total		117	7.3 (6.1 to 8.8)	141.0 (117.6 to 169.0)	47.0
Tackler No.					
	1	57	3.6 (2.8 to 4.6)	68.7 (53.0 to 89.0)	48.7
	2	48	3.0 (2.3 to 4.0)	57.8 (43.6 to 76.7)	41.0
	3	9	0.6 (0.3 to 1.1)	10.8 (5.6 to 20.8)	7.7
	4 or more	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.6
Tackle Height					
	Head/Neck	11	0.7 (0.4 to 1.2)	13.3 (7.3 to 23.9)	9.4
	Shoulder	44	2.8 (2.1 to 3.7)	53.0 (39.5 to 71.2)	37.6
	Mid Torso	34	2.1 (1.5 to 3.0)	41.0 (29.3 to 57.3)	29.1
	Hip / Thigh	21	1.3 (0.9 to 2.0)	25.3 (16.5 to 38.8)	17.9
	Lower Legs	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	6.0
Degree of Tackle Position					
	300-330	19	1.2 (0.8 to 1.9)	22.9 (14.6 to 35.9)	16.2
	330-360	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	11.1
	0-30	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	11.1
	30-60	22	1.4 (0.9 to 2.1)	26.5 (17.5 to 40.3)	18.8
	60-300	50	3.1 (2.4 to 4.1)	60.2 (45.7 to 79.5)	42.7
Match Time					
	1st Quarter	16	1.0 (0.6 to 1.6)	77.1 (47.2 to 125.9)	13.7
	2nd Quarter	23	1.4 (1.0 to 2.2)	110.9 (73.7 to 166.8)	19.7
	3rd Quarter	42	2.6 (1.9 to 3.6)	202.4 (149.6 to 273.9)	35.9
	4th Quarter	36	2.3 (1.6 to 3.1)	173.5 (125.2 to 240.5)	30.8
Field Position					
Defence	In Goal	1	0.1 (0.0 to 0.4)	1.2 (0.2 to 8.6)	0.9
Defence	0-10	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	8.5
Defence	10-20	8	0.5 (0.3 to 1.0)	9.6 (4.8 to 19.3)	6.8
Defence	20-30	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	6.0
Defence	30-40	12	0.8 (0.4 to 1.3)	14.5 (8.2 to 25.5)	10.3
Defence	40-50	13	0.8 (0.5 to 1.4)	15.7 (9.1 to 27.0)	11.1
Attack	50-40	17	1.1 (0.7 to 1.7)	20.5 (12.7 to 33.0)	14.5
Attack	40-30	18	1.1 (0.7 to 1.8)	21.7 (13.7 to 34.4)	15.4
Attack	30-20	9	0.6 (0.3 to 1.1)	10.8 (5.6 to 20.8)	7.7
Attack	20-10	12	0.8 (0.4 to 1.3)	14.5 (8.2 to 25.5)	10.3
Attack	10-0	8	0.5 (0.3 to 1.0)	9.6 (4.8 to 19.3)	6.8
Attack	In Goal	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.7
Injury Severity					
	Transient (0 - 4 days)	101	6.3 (5.2 to 7.7)	121.7 (100.1 to 147.9)	86.3
	Mild (4 - 7 days)	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	8.5
	Moderate (7 - 21 days)	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.7
	Major (21 days +)	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.4
Tackle No.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	22	1.4 (0.9 to 2.1)	26.5 (17.5 to 40.3)	18.8
	Tackle 2	27	1.7 (1.2 to 2.5)	32.5 (22.3 to 47.4)	23.1
	Tackle 3	28	1.8 (1.2 to 2.5)	33.7 (23.3 to 48.9)	23.9
	Tackle 4	24	1.5 (1.0 to 2.2)	28.9 (19.4 to 43.1)	20.5
	Tackle 5	16	1.0 (0.6 to 1.6)	19.3 (11.8 to 31.5)	13.7
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 6: Tackler tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		Injury rate per 1000		
		Tackle events	Match hours	
	No.	Rate (95% CI)	Rate (95% CI)	%
Player No.				
1. Fullback	5	4.1 (1.7 to 9.8)	78.3 (32.6 to 188.2)	4.3
2. Wing	1	0.8 (0.1 to 5.8)	15.7 (2.2 to 111.2)	0.9
3. Centre	7	5.7 (2.7 to 12.0)	109.6 (52.3 to 230.0)	6.0
4. Centre	5	4.1 (1.7 to 9.8)	78.3 (32.6 to 188.2)	4.3
5. Wing	4	3.3 (1.2 to 8.7)	62.7 (23.5 to 166.9)	3.4
6. Stand Off	6	4.9 (2.2 to 10.9)	94.0 (42.2 to 209.2)	5.1
7. Half back	14	11.4 (6.8 to 19.2)	219.3 (129.9 to 370.3)	12.0
8. Prop	14	11.4 (6.8 to 19.2)	219.3 (129.9 to 370.3)	12.0
9. Hooker	22	17.9 (11.8 to 27.2)	344.6 (226.9 to 523.4)	18.8
10. Prop	8	6.5 (3.3 to 13.0)	125.3 (62.7 to 250.6)	6.8
11. second row	8	6.5 (3.3 to 13.0)	125.3 (62.7 to 250.6)	6.8
12. Second row	17	13.8 (8.6 to 22.3)	266.3 (165.5 to 428.4)	14.5
13. Loose Forward	6	4.9 (2.2 to 10.9)	94.0 (42.2 to 209.2)	5.1
Forwards	75	10.2 (8.1 to 12.8)	195.8 (156.1 to 245.5)	64.1
Backs	42	4.9 (3.6 to 6.6)	94.0 (69.5 to 127.2)	35.9
Injury Type				
Abrasions	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.7
Sprains	22	1.4 (0.9 to 2.1)	26.5 (17.5 to 40.3)	18.8
Strains	31	1.9 (1.4 to 2.8)	37.4 (26.3 to 53.1)	26.5
Lacerations	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.4
Bruise	37	2.3 (1.7 to 3.2)	44.6 (32.3 to 61.5)	31.6
Inflammation	1	0.1 (0.0 to 0.4)	1.2 (0.2 to 8.6)	0.9
Fracture	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.6
Dislocation	6	0.4 (0.2 to 0.8)	7.2 (3.2 to 16.1)	5.1
Cramp	1	0.1 (0.0 to 0.4)	1.2 (0.2 to 8.6)	0.9
Concussion	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	6.0
Other	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.6
Injury Site				
Head	14	0.9 (0.5 to1.5)	16.9 (10.0 to 28.5)	12.0
Neck	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.4
Shoulder	18	1.1 (0.7 to 1.8)	21.7 (13.7 to 34.4)	15.4
U Arm	7	0.4 (0.2 to 0.9)	8.4 (4.0 to 17.7)	6.0
Elbow	12	0.8 (0.4 to 1.3)	14.5 (8.2 to 25.5)	10.3
L Arm	3	0.2 (0.1 to 0.6)	3.6 (1.2 to 11.2)	2.6
Wrist	5	0.3 (0.1 to 0.8)	6.0 (2.5 to 14.5)	4.3
Hand	6	0.4 (0.2 to 0.8)	7.2 (3.2 to 16.1)	5.1
Finger	5	0.3 (0.1 to 0.8)	6.0 (2.5 to 14.5)	4.3
Chest	9	0.6 (0.3 to 1.1)	10.8 (5.6 to 20.8)	7.7
Back	2	0.1 (0.0 to 0.5)	2.4 (0.6 to 9.6)	1.7
Groin	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.4
Hamstring	1	0.1 (0.0 to 0.4)	1.2 (0.2 to 8.6)	0.9
Quadriceps	4	0.3 (0.1 to 0.7)	4.8 (1.8 to 12.8)	3.4
Knee	10	0.6 (0.3 to 1.2)	12.0 (6.5 to 22.4)	8.5
Lower Leg	8	0.5 (0.3 to 1.0)	9.6 (4.8 to 19.3)	6.8
Ankle	5	0.3 (0.1 to 0.8)	6.0 (2.5 to 14.5)	4.3
Injury Region				
Head/Neck	18	1.1 (0.7 to 1.8)	21.7 (13.7 to 34.4)	15.4
Upper Limb	56	3.5 (2.7 to 4.6)	67.5 (51.9 to 87.7)	47.9
Chest/Back	11	0.7 (0.4 to 1.2)	13.3 (7.3 to 23.9)	9.4
Lower Limb	32	2.0 (1.4 to 2.8)	38.6 (27.3 to 54.5)	27.4

Appendix 7: Supplemental data for Chapter 11

Nature of tackles that result in injury by positional group in professional rugby league

Tackle Injury data

Table 1: Total outside backs tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

			Injury rate per 1000		
		No.	Tackle events Rate (95% CI)	Match hours Rate (95% CI)	%
Total		74	5.8 (4.6 to 7.3)	231.8 (184.6 to 291.2)	100.0
Number of Tacklers					
	1	33	1.0 (0.7 to 1.5)	103.4 (73.5 to 145.4)	44.6
	2	32	1.0 (0.7 to 1.4)	100.3 (70.9 to 141.8)	43.2
	3	8	0.3 (0.1 to 0.5)	25.1 (12.5 to 50.1)	10.8
	4 or more	1	0.0 (0.0 to 0.2)	3.1 (0.4 to 22.2)	1.4
Tackle Height					
	Head/Neck	22	0.7 (0.5 to 1.1)	68.9 (45.4 to 104.7)	29.7
	Shoulder	32	1.0 (0.7 to 1.4)	100.3 (70.9 to 141.8)	43.2
	Mid Torso	34	1.1 (0.8 to 1.5)	106.5 (76.1 to 149.1)	45.9
	Hip / Thigh	17	0.5 (0.3 to 0.9)	53.3 (33.1 to 85.7)	23.0
	Lower Legs	5	0.2 (0.1 to 0.4)	15.7 (6.5 to 37.6)	6.8
Direction					
	Left Front	16	0.5 (0.3 to 0.8)	50.1 (30.7 to 81.8)	21.6
	Front	16	0.5 (0.3 to 0.8)	50.1 (30.7 to 81.8)	21.6
	Right Front	19	0.6 (0.4 to 0.9)	59.5 (38.0 to 93.3)	25.7
	Side	41	1.3 (1.0 to 1.8)	128.4 (94.6 to 174.4)	55.4
	Behind	10	0.3 (0.2 to 0.6)	31.3 (16.9 to 58.2)	13.5
Degree of Tackler Position					
	300°-330°	16	0.5 (0.3 to 0.8)	50.1 (30.7 to 81.8)	21.6
	330°-360°	12	0.4 (0.2 to 0.7)	37.6 (21.3 to 66.2)	16.2
	000°-030°	10	0.3 (0.2 to 0.6)	31.3 (16.9 to 58.2)	13.5
	030°-060°	19	0.6 (0.4 to 0.9)	59.5 (38.0 to 93.3)	25.7
	060°-300°	27	0.9 (0.6 to 1.2)	84.6 (58.0 to 123.3)	36.5
Match Time					
	1st Quarter	16	1.3 (0.8 to 2.1)	200.5 (122.8 to 327.3)	21.6
	2nd Quarter	15	1.2 (0.7 to 2.0)	188.0 (113.3 to 311.8)	20.3
	3rd Quarter	21	1.7 (1.1 to 2.5)	263.2 (171.6 to 403.6)	28.4
	4th Quarter	22	1.7 (1.1 to 2.6)	275.7 (181.5 to 418.7)	29.7
Field Position					
Defence	In Goal	2	0.1 (0.0 to 0.3)	6.3 (1.6 to 25.1)	2.7
Defence	0-10	5	0.2 (0.1 to 0.4)	15.7 (6.5 to 37.6)	6.8
Defence	10-20	6	0.2 (0.1 to 0.4)	18.8 (8.4 to 41.8)	8.1
Defence	20-30	8	0.3 (0.1 to 0.5)	25.1 (12.5 to 50.1)	10.8
Defence	30-40	11	0.3 (0.2 to 0.6)	34.5 (19.1 to 62.2)	14.9
Defence	40-50	8	0.3 (0.1 to 0.5)	25.1 (12.5 to 50.1)	10.8
Attack	50-40	6	0.2 (0.1 to 0.4)	18.8 (8.4 to 41.8)	8.1
Attack	40-30	6	0.2 (0.1 to 0.4)	18.8 (8.4 to 41.8)	8.1
Attack	30-20	10	0.3 (0.2 to 0.6)	31.3 (16.9 to 58.2)	13.5
Attack	20-10	4	0.1 (0.0 to 0.3)	12.5 (4.7 to 33.4)	5.4
Attack	10-0	6	0.2 (0.1 to 0.4)	18.8 (8.4 to 41.8)	8.1
Attack	In Goal	2	0.1 (0.0 to 0.3)	6.3 (1.6 to 25.1)	2.7
Injury Severity					
	Transient (0 - 4 days)	60	1.9 (1.5 to 2.4)	188.0 (145.9 to 242.1)	81.1
	Mild (4 - 7 days)	9	0.3 (0.1 to 0.5)	28.2 (14.7 to 54.2)	12.2
	Moderate (7 - 21 days)	0	0.0 -	0.0 -	0.0
	Major (21 days +)	4	0.1 (0.0 to 0.3)	12.5 (4.7 to 33.4)	5.4
Tackle no.					
	Tackle 0	2	0.1 (0.0 to 0.4)	6.3 (1.6 to 25.1)	2.7
	Tackle 1	19	0.9 (0.6 to 1.4)	59.5 (38.0 to 93.3)	25.7
	Tackle 2	16	0.7 (0.4 to 1.2)	50.1 (30.7 to 81.8)	21.6
	Tackle 3	10	0.5 (0.2 to 0.8)	31.3 (16.9 to 58.2)	13.5
	Tackle 4	16	0.7 (0.4 to 1.2)	50.1 (30.7 to 81.8)	21.6
	Tackle 5	9	0.4 (0.2 to 0.8)	28.2 (14.7 to 54.2)	12.2
	Tackle 6	1	0.0 (0.0 to 0.3)	3.1 (0.4 to 22.2)	1.4
	Incomplete Tackle	1	0.0 (0.0 to 0.3)	3.1 (0.4 to 22.2)	1.4

Table 2: Outside backs total tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Match hours Rate (95% CI)	%
Position				
1. Fullback	18	7.4 (4.7 to 11.7)	282.0 (177.6 to 447.5)	24.3
2. Wing	8	3.3 (1.6 to 6.6)	125.3 (62.7 to 250.6)	10.8
3. Centre	20	8.2 (5.3 to 12.7)	313.3 (202.1 to 485.6)	27.0
4. Centre	15	6.2 (3.7 to 10.2)	235.0 (141.6 to 389.7)	20.3
5. Wing	13	5.3 (3.1 to 9.2)	203.6 (118.2 to 350.7)	17.6
Backs	74	4.3 (3.5 to 5.5)	165.6 (131.9 to 208.0)	100.0
Injury Type				
Sprains	17	7.0 (4.3 to 11.2)	53.3 (33.1 to 85.7)	23.0
Strains	20	8.2 (5.3 to 12.7)	62.7 (40.4 to 97.1)	27.0
Lacerations	3	1.2 (0.4 to 3.8)	9.4 (3.0 to 29.1)	4.1
Bruise	24	9.9 (6.6 to 14.7)	75.2 (50.4 to 112.2)	32.4
Inflammation	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Fracture	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Dislocation	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Concussion	4	1.6 (0.6 to 4.4)	12.5 (4.7 to 33.4)	5.4
Other	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Injury Site				
Head	7	2.9 (1.4 to 6.0)	21.9 (10.5 to 46.0)	9.5
Eye	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Mouth	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Neck	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Shoulder	8	3.3 (1.6 to 6.6)	25.1 (12.5 to 50.1)	10.8
Upper Arm	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Elbow	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Wrist	2	0.8 (0.2 to 3.3)	6.3 (1.6 to 25.1)	2.7
Finger	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Chest	7	2.9 (1.4 to 6.0)	21.9 (10.5 to 46.0)	9.5
Back	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Groin	7	2.9 (1.4 to 6.0)	21.9 (10.5 to 46.0)	9.5
Hamstring	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Quadriceps	10	4.1 (2.2 to 7.6)	31.3 (16.9 to 58.2)	13.5
Knee	9	3.7 (1.9 to 7.1)	28.2 (14.7 to 54.2)	12.2
Lower Leg	6	2.5 (1.1 to 5.5)	18.8 (8.4 to 41.8)	8.1
Ankle	5	2.1 (0.9 to 4.9)	15.7 (6.5 to 37.6)	6.8
Toe	1	0.4 (0.1 to 2.9)	3.1 (0.4 to 22.2)	1.4
Injury Region				
Head/Neck	11	4.5 (2.5 to 8.2)	34.5 (19.1 to 62.2)	14.9
Upper Limb	16	6.6 (4.0 to 10.7)	50.1 (30.7 to 81.8)	21.6
Chest/Back	8	3.3 (1.6 to 6.6)	25.1 (12.5 to 50.1)	10.8
Lower Limb	39	16.0 (11.7 to 21.9)	122.2 (89.3 to 167.2)	52.7

Table 3: Outside backs as ball carrier tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Total		52	8.6 (6.6 to 11.3)	162.9 (124.1 to 213.8)	70.3
Number of Tacklers					
	1	16	2.7 (1.6 to 4.3)	50.1 (30.7 to 81.8)	30.8
	2	27	4.5 (3.1 to 6.5)	84.6 (58.0 to 123.3)	51.9
	3	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
	4 or more	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Tackle Height					
	Head/Neck	21	3.5 (2.3 to 5.3)	65.8 (42.9 to 100.9)	40.4
	Shoulder	25	4.1 (2.8 to6.1)	78.3 (52.9 to 115.9)	48.1
	Mid Torso	26	4.3 (2.9 to 6.3)	81.5 (55.5 to 119.6)	50.0
	Hip / Thigh	12	2.0 (1.1 to 3.5)	37.6 (21.3 to 66.2)	23.1
	Lower Legs	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
Degree of Tackler Position					
	300°-330°	14	2.3 (1.4 to 3.9)	43.9 (26.0 to 74.1)	26.9
	330°-360°	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
	000°-030°	7	1.2 (0.6 to 2.4)	21.9 (10.5 to 46.0)	13.5
	030°-060°	16	2.7 (1.6 to 4.3)	50.1 (30.7 to 81.8)	30.8
	060°-300°	18	3.0 (1.9 to 4.7)	56.4 (35.5 to 89.5)	34.6
Match Time					
	1st Quarter	14	2.3 (1.4 to 3.9)	175.4 (103.9 to 296.2)	26.9
	2nd Quarter	10	1.7 (0.9 to 3.1)	125.3 (67.4 to 232.9)	19.2
	3rd Quarter	14	2.3 (1.4 to 3.9)	175.4 (103.9 to 296.2)	26.9
	4th Quarter	14	2.3 (1.4 to 3.9)	175.4 (103.9 to 296.2)	26.9
Field Position					
Defence	In Goal	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
	0-10	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
	10-20	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
	20-30	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
	30-40	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
	40-50	6	1.0 (0.4 to 2.2)	18.8 (8.4 to 41.8)	11.5
Attack	50-40	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	5.8
	40-30	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
	30-20	7	1.2 (0.6 to 2.4)	21.9 (10.5 to 46.0)	13.5
	20-10	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	3.8
	10-0	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
	In Goal	0	0.0 -	0.0 -	0.0
Injury Severity					
	Transient (0 - 4 days)	42	7.0 (5.1 to 9.4)	131.6 (97.2 to 178.0)	80.8
	Mild (4 - 7 days)	6	1.0 (0.4 to 2.2)	18.8 (8.4 to 41.8)	11.5
	Moderate (7 - 21 days)	0	0.0 -	0.0 -	0.0
	Major (21 days +)	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
Tackle no.					
	Tackle 0	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	3.8
	Tackle 1	14	2.3 (1.4 to 3.9)	43.9 (26.0 to 74.1)	26.9
	Tackle 2	13	2.2 (1.3 to 3.7)	40.7 (23.6 to 70.1)	25.0
	Tackle 3	6	1.0 (0.4 to 2.2)	18.8 (8.4 to 41.8)	11.5
	Tackle 4	9	1.5 (0.8 to 2.9)	28.2 (14.7 to 54.2)	17.3
	Tackle 5	6	1.0 (0.4 to 2.2)	18.8 (8.4 to 41.8)	11.5
	Tackle 6	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
	Incomplete Tackle	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9

Table 4: Outside backs as ball carrier tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000		%
		Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	
Player Position.				
1. Fullback	13	2.2 (1.3 to 3.7)	203.6 (118.2 to 350.7)	25.0
2. Wing	7	1.2 (0.6 to 2.4)	109.6 (52.3 to 230.0)	13.5
3. Centre	13	2.2 (1.3 to 3.7)	203.6 (118.2 to 350.7)	25.0
4. Centre	10	1.7 (0.9 to 3.1)	156.6 (84.3 to 291.1)	19.2
5. Wing	9	1.5 (0.8 to 2.9)	141.0 (73.4 to 270.9)	17.3
Backs	52	8.6 (6.6 to 11.3)	116.4 (88.7 to 152.7)	100.0
Injury Type				
Sprains	13	2.2 (1.3 to 3.7)	40.7 (23.6 to 70.1)	25.0
Strains	10	1.7 (0.9 to 3.1)	31.3 (16.9 to 58.2)	19.2
Lacerations	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	5.8
Bruise	19	3.1 (2.0 to 4.9)	59.5 (38.0 to 93.3)	36.5
Fracture	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	3.8
Dislocation	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Concussion	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	5.8
Other	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Injury Site				
Head	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Eye	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Mouth	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Neck	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Shoulder	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Upper Arm	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	3.8
Chest	4	0.7 (0.2 to 1.8)	12.5 (4.7 to 33.4)	7.7
Back	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Groin	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Quadriceps	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
Knee	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
Lower Leg	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Ankle	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Toe	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	1.9
Injury Region				
Head/Neck	8	1.3 (0.7 to 2.7)	25.1 (12.5 to 50.1)	15.4
Upper Limb	7	1.2 (0.6 to 2.4)	21.9 (10.5 to 46.0)	13.5
Chest/Back	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	9.6
Lower Limb	32	5.3 (3.7 to 7.5)	100.3 (70.9 to 141.8)	61.5

Table 5: Outside backs as the tackler tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Total		22	3.6 (2.4 to 5.4)	68.9 (45.4 to 104.7)	29.7
Tackler No.					
	1	17	2.8 (1.7 to 4.5)	53.3 (33.1 to 85.7)	77.3
	2	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	22.7
	3	0	0.0 -	0.0 -	0.0
	4 or more	0	0.0 -	0.0 -	0.0
Tackle Height					
	Head/Neck	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
	Shoulder	7	1.1 (0.5 to 2.4)	21.9 (10.5 to 46.0)	31.8
	Mid Torso	8	1.3 (0.7 to 2.6)	25.1 (12.5 to50.1)	36.4
	Hip / Thigh	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	22.7
	Lower Legs	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Degree of Tackle Position					
	300°-330°	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
	330°-360°	4	0.7 (0.2 to 1.7)	12.5 (4.7 to 33.4)	18.2
	000°-030°	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
	030°-060°	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
	060°-300°	9	1.5 (0.8 to 2.8)	28.2 (14.7 to 54.2)	40.9
Match Time					
	1st Quarter	2	0.3 (0.1 to 1.3)	25.1 (6.3 to 100.2)	9.1
	2nd Quarter	5	0.8 (0.3 to 2.0)	62.7 (26.1 to 150.5)	22.7
	3rd Quarter	7	1.1 (0.5 to 2.4)	87.7 (41.8 to 184.0)	31.8
	4th Quarter	8	1.3 (0.7 to 2.6)	100.3 (50.1 to 200.5)	36.4
Field Position					
Defence	In Goal	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Defence	0-10	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Defence	10-20	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Defence	20-30	0	0.0 -	0.0 -	0.0
Defence	30-40	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Defence	40-50	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Defence	50-40	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Attack	40-30	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Attack	30-20	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Attack	20-10	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Attack	10-0	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Attack	In Goal	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Injury Severity					
	Transient (0 - 4 days)	18	2.9 (1.8 to 4.7)	56.4 (35.5 to 89.5)	81.8
	Mild (4 - 7 days)	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
	Moderate (7 - 21 days)	0	0.0 -	0.0 -	0.0
	Major (21 days +)	0	0.0 -	0.0 -	0.0
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	5	0.3 (0.1 to 0.8)	15.7 (6.5 to 37.6)	22.7
	Tackle 2	3	0.2 (0.1 to 0.6)	9.4 (3.0 to 29.1)	13.6
	Tackle 3	4	0.3 (0.1 to 0.7)	12.5 (4.7 to 33.4)	18.2
	Tackle 4	7	0.4 (0.2 to 0.9)	21.9 (10.5 to 46.0)	31.8
	Tackle 5	3	0.2 (0.1 to 0.6)	9.4 (3.0 to 29.1)	13.6
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 6: Outside backs as the tackler tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Player No.				
1. Fullback	5	0.8 (0.3 to 2.0)	78.3 (32.6 to 188.2)	22.7
2. Wing	1	0.2 (0.0 to 1.2)	15.7 (2.2 to 111.2)	4.5
3. Centre	7	1.1 (0.5 to 2.4)	109.6 (52.3 to 230.0)	31.8
4. Centre	5	0.8 (0.3 to 2.0)	78.3 (32.6 to 188.2)	22.7
5. Wing	4	0.7 (0.2 to 1.7)	62.7 (23.5 to 166.9)	18.2
Backs	22	3.6 (2.4 to 5.4)	49.2 (32.4 to 74.8)	100.0
Injury Type				
Sprains	4	0.7 (0.2 to 1.7)	12.5 (4.7 to 33.4)	18.2
Strains	10	1.6 (0.9 to 3.0)	31.3 (16.9 to 58.2)	45.5
Bruise	5	0.8 (0.3 to 2.0)	15.7 (6.5 to 37.6)	22.7
Inflammation	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Concussion	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Other	1	0.2 (0.0 to .2)	3.1 (0.4 to 22.2)	4.5
Injury Site				
Head	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Neck	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Shoulder	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Elbow	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Wrist	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Finger	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Chest	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Groin	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Hamstring	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Quadriceps	2	0.3 (0.1 to 1.3)	6.3 (1.6 to 25.1)	9.1
Knee	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Lower Leg	1	0.2 (0.0 to 1.2)	3.1 (0.4 to 22.2)	4.5
Injury Region				
Head/Neck	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Upper Limb	9	1.5 (0.8 to 2.8)	28.2 (14.7 to 54.2)	40.9
Chest/Back	3	0.5 (0.2 to 1.5)	9.4 (3.0 to 29.1)	13.6
Lower Limb	7	1.1 (0.5 to 2.4)	21.9 (10.5 to 46.0)	31.8

Table 7: Total Adjustables tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Total		75	7.7 (6.1 to 9.7)	293.7 (234.2 to 368.3)	100.0
Number of Tacklers					
	1	35	3.6 (2.6 to 5.0)	137.1 (98.4 to 190.9)	46.7
	2	29	3.0 (2.1 to 4.3)	113.6 (78.9 to 163.4)	38.7
	3	8	0.8 (0.4 to 1.6)	31.3 (15.7 to 62.6)	10.7
	4 or more	3	0.3 (0.1 to 1.0)	11.7 (3.8 to 36.4)	4.0
Tackle Height					
	Head/Neck	21	2.2 (1.4 to 3.3)	82.2 (53.6 to 126.1)	22.6
	Shoulder	26	2.7 (1.8 to 3.9)	101.8 (69.3 to 149.5)	28.0
	Mid Torso	18	1.8 (1.2 to 2.9)	70.5 (44.4 to 111.9)	19.4
	Hip / Thigh	22	2.3 (1.5 to 3.4)	86.2 (56.7 to 130.8)	23.7
	Lower Legs	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	6.5
Degree of Tackler Position					
	300°-330°	22	2.3 (1.5 to 3.4)	86.2 (56.7 to 130.8)	26.2
	330°-360°	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	7.1
	000°-030°	10	1.0 (0.6 to 1.9)	39.2 (21.1 to 72.8)	11.9
	030°-060°	16	1.6 (1.0 to 2.7)	62.7 (38.4 to 102.3)	19.0
	060°-300°	30	3.1 (2.2 to 4.4)	117.5 (82.1 to 168.0)	35.7
Match Time					
	1st Quarter	14	1.4 (0.9 to 2.4)	219.3 (129.9 to 370.3)	18.7
	2nd Quarter	11	1.1 (0.6 to 2.0)	172.3 (95.4 to 311.1)	14.7
	3rd Quarter	29	3.0 (2.1 to 4.3)	454.3 (315.7 to 653.7)	38.7
	4th Quarter	21	2.2 (1.4 to 3.3)	328.9 (214.5 to 504.5)	28.0
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
Defence	0-10	3	0.3 (0.1 to 1.0)	11.7 (3.8 to 36.4)	4.0
Defence	10-20	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	8.0
Defence	20-30	7	0.7 (0.3 to 1.5)	27.4 (13.1 to 57.5)	9.3
Defence	30-40	8	0.8 (0.4 to 1.6)	31.3 (15.7 to 62.6)	10.7
Defence	40-50	11	1.1 (0.6 to 2.0)	43.1 (23.9 to 77.8)	14.7
Attack	50-40	5	0.5 (0.2 to 1.2)	19.6 (8.1 to 47.0)	6.7
Attack	40-30	8	0.8 (0.4 to 1.6)	31.3 (15.7 to 62.6)	10.7
Attack	30-20	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	8.0
Attack	20-10	9	0.9 (0.5 to 1.8)	35.2 (18.3 to 67.7)	12.0
Attack	10-0	12	1.2 (0.7 to 2.2)	47.0 (26.7 to 82.7)	16.0
Attack	In Goal	0	0.0 -	0.0 -	0.0
Injury Severity					
	Transient (0 - 4 days)	59	6.1 (4.7 to 7.8)	231.0 (179.0 to 298.2)	78.7
	Mild (4 - 7 days)	8	0.8 (0.4 to 1.6)	31.3 (15.7 to 62.6)	10.7
	Moderate (7 - 21 days)	2	0.2 (0.1 to 0.8)	7.8 (2.0 to 31.3)	2.7
	Major (21 days +)	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	8.0
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	13	0.6 (0.4 to 1.1)	50.9 (29.6 to 87.7)	17.3
	Tackle 2	21	1.0 (0.7 to 1.5)	82.2 (53.6 to 126.1)	28.0
	Tackle 3	14	0.7 (0.4 to 1.1)	54.8 (32.5 to 92.6)	18.7
	Tackle 4	11	0.5 (0.3 to 1.0)	43.1 (23.9 to 77.8)	14.7
	Tackle 5	14	0.7 (0.4 to 1.1)	54.8 (32.5 to 92.6)	18.7
	Tackle 6	1	0.0 (0.0 to 0.3)	3.9 (0.6 to 27.8)	1.3
	Incomplete Tackle	1	0.0 (0.0 to 0.3)	3.9 (0.6 to 27.8)	1.3

Table 8: Total Adjustables tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Position				
6. Stand Off	13	10.6 (6.1 to 18.2)	203.6 (118.2 to 350.7)	17.3
7. Half back	20	16.3 (10.5 to 25.2)	313.3 (202.1 to 485.6)	26.7
9. Hooker	26	21.2 (14.4 to 31.1)	407.3 (277.3 to 598.2)	34.7
13. Loose Forward	16	13.0 (8.0 to 21.3)	250.6 (153.5 to 409.1)	21.3
Forwards	42	5.7 (4.2 to 7.7)	109.6 (81.0 to 148.4)	56.0
Backs	33	3.8 (2.7 to 5.4)	70.7 (50.2 to 99.4)	44.0
Injury Type				
Sprains	18	14.7 (9.2 to 23.3)	70.5 (44.4 to 111.9)	24.0
Strains	15	12.2 (7.4 to 20.3)	58.7 (35.4 to 97.4)	20.0
Lacerations	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Bruise	26	21.2 (14.4 to 31.1)	101.8 (69.3 to 149.5)	34.7
Fracture	10	8.1 (4.4 to 15.1)	39.2 (21.1 to 72.8)	13.3
Dislocation	4	3.3 (1.2 to 8.7)	15.7 (5.9 to 41.7)	5.3
Cramp	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.3
Concussion	6	4.9 (2.2 to 10.9)	23.5 (10.6 to 52.3)	8.0
Other	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.3
Injury Site				
Head	8	6.5 (3.3 to 13.0)	31.3 (15.7 to 62.6)	10.7
Nose	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.3
Neck	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Shoulder	8	6.5 (3.3 to 13.0)	31.3 (15.7 to 62.6)	10.7
Upper Arm	6	4.9 (2.2 to 10.9)	23.5 (10.6 to 52.3)	8.0
Elbow	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	6.7
Lower Arm	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Wrist	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Hand	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	6.7
Finger	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Chest	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Groin	6	4.9 (2.2 to 10.9)	23.5 (10.6 to 52.3)	8.0
Quadriceps	6	4.9 (2.2 to 10.9)	23.5 (10.6 to 52.3)	8.0
Knee	10	8.1 (4.4 to 15.1)	39.2 (21.1 to 72.8)	13.3
Lower Leg	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	6.7
Ankle	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	6.7
Toe	1	0.8 (0.1 to 5.8)	3.9 (90.6 to 27.8)	1.3
Injury Region				
Head/Neck	11	9.0 (5.0 to 16.2)	43.1 (23.9 to 77.8)	14.7
Upper Limb	30	24.4 (17.1 to 34.9)	117.5 (82.1 to 168.0)	40.0
Chest/Back	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.7
Lower Limb	32	26.1 (18.4 to 36.8)	125.3 (88.6 to 177.2)	42.7

Table 9: Adjustables as the ball carrier tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Injury rate per 1000 Tackle events Rate (95% CI)	%
Total		27	5.6 (3.8 to 8.2)	105.7 (72.5 to 154.2)	36.0
Number of Tacklers					
	1	10	2.1 (1.1 to 3.8)	39.2 (21.1 to 72.8)	37.0
	2	11	2.3 (1.3 to 4.1)	43.1 (23.9 to 77.8)	40.7
	3	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	18.5
	4 or more	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Tackle Height					
	Head/Neck	15	3.1 (1.9 to 5.2)	58.7 (35.4 to 97.4)	33.3
	Shoulder	12	2.5 (1.4 to 4.4)	47.0 (26.7 to 82.7)	26.7
	Mid Torso	8	1.7 (0.8 to 3.3)	31.3 (15.7 to 62.6)	17.8
	Hip / Thigh	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	20.0
	Lower Legs	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	2.2
Degree of Tackler Position					
	300°-330°	8	1.7 (0.8 to 3.3)	31.3 (15.7 to 62.6)	23.5
	330°-360°	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	8.8
	000°-030°	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	14.7
	030°-060°	6	1.2 (0.6 to 2.8)	23.5 (10.6 to 52.3)	17.6
	060°-300°	12	2.5 (1.4 to 4.4)	47.0 (26.7 to 82.7)	35.3
Match Time					
	1st Quarter	7	1.4 (0.7 to 3.0)	109.6 (52.3 to 230.0)	25.9
	2nd Quarter	3	0.6 (0.2 to 1.9)	47.0 (15.2 to 145.7)	11.1
	3rd Quarter	10	2.1 (1.1 to 3.8)	156.6 (84.3 to 291.1)	37.0
	4th Quarter	7	1.4 (0.7 to 3.0)	109.6 (52.3 to 230.0)	25.9
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
	0-10	0	0.0 -	0.0 -	0.0
	10-20	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
	20-30	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
	30-40	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	18.5
	40-50	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
Attack	50-40	0	0.0 -	0.0 -	0.0
	40-30	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
	30-20	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
	20-10	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
	10-0	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	25.9
	In Goal	0	0.0 -	0.0 -	0.0
Injury Severity					
	Transient (0 - 4 days)	20	4.1 (2.7 to 6.4)	78.3 (50.5 to 121.4)	74.1
	Mild (4 - 7 days)	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
	Moderate (7 - 21 days)	0	0.0 -	0.0 -	0.0
	Major (21 days +)	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
	Tackle 2	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	33.3
	Tackle 3	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
	Tackle 4	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
	Tackle 5	6	1.2 (0.6 to 2.8)	23.5 (10.6 to 52.3)	22.2
	Tackle 6	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
	Incomplete Tackle	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7

Table 10: Adjustables as the ball carrier tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Player Position.				
6. Stand Off	7	5.7 (2.7 to 12.0)	109.6 (52.3 to 230.0)	25.9
7. Half back	6	4.9 (2.2 to 10.9)	94.0 (42.2 to 209.2)	22.2
9. Hooker	4	3.3 (1.2 to 8.7)	62.7 (23.5 to 166.9)	14.8
13. Loose Forward	10	8.1 (4.4 to 15.1)	156.6 (84.3 to 291.1)	37.0
Forwards	14	1.9 (1.1 to 3.2)	36.5 (21.6 to 61.7)	51.9
Backs	13	1.5 (0.9 to 2.6)	27.8 (16.2 to 48.0)	48.1
Injury Type				
Sprains	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	25.9
Strains	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	25.9
Bruise	11	2.3 (1.3 to 4.1)	43.1 (23.9 to 77.8)	40.7
Fracture	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	11.1
Dislocation	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Concussion	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Injury Site				
Head	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Nose	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Neck	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Shoulder	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Upper Arm	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Hand	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Chest	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Groin	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	18.5
Quadriceps	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	18.5
Knee	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
Lower Leg	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Ankle	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	3.7
Injury Region				
Head/Neck	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
Upper Limb	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	14.8
Chest/Back	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	7.4
Lower Limb	17	3.5 (2.2 to 5.7)	66.6 (41.4 to 107.1)	63.0

Table 11: Adjustables as the tackler tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Total		48	9.8 (7.4 to 13.0)	188.0 (141.7 to 249.4)	64.0
Tackler No.					
	1	25	5.1 (3.4 to 7.5)	97.9 (66.2 to 144.9)	52.1
	2	18	3.7 (2.3 to 5.8)	70.5 (44.4 to 111.9)	37.5
	3	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
	4 or more	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
Tackle Height					
	Head/Neck	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.5
	Shoulder	14	2.9 (1.7 to 4.8)	54.8 (32.5 to 92.6)	29.2
	Mid Torso	10	2.0 (1.1 to 3.8)	39.2 (21.1 to 72.8)	20.8
	Hip / Thigh	13	2.6 (1.5 to 4.6)	50.9 (29.6 to 87.7)	27.1
	Lower Legs	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
Degree of Tackle Position					
	300°-330°	14	2.9 (1.7 to 4.8)	54.8 (32.5 to 92.6)	29.2
	330°-360°	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
	000°-030°	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
	030°-060°	10	2.0 (1.1 to 3.8)	39.2 (21.1 to 72.8)	20.8
	060°-300°	18	3.7 (2.3 to 5.8)	70.5 (44.4 to 111.9)	37.5
Match Time					
	1st Quarter	7	1.4 (0.7 to 3.0)	109.6 (52.3 to 230.0)	14.6
	2nd Quarter	8	1.6 (0.8 to 3.3)	125.3 (62.7 to 250.6)	16.7
	3rd Quarter	19	3.9 (2.5 to 6.1)	297.6 (189.8 to 466.6)	39.6
	4th Quarter	14	2.9 (1.7 to 4.8)	219.3 (129.9 to 370.3)	29.2
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
	0-10	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
	10-20	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
	20-30	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
	30-40	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
	40-50	8	1.6 (0.8 to 3.3)	31.3 (15.7 to 62.6)	16.7
Attack	50-40	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
	40-30	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	14.6
	30-20	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
	20-10	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	14.6
	10-0	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
	In Goal	0	0.0 -	0.0 -	0.0
Injury Severity					
	Transient (0 - 4 days)	39	7.9 (5.8 to 10.9)	152.7 (111.6 to 209.0)	81.3
	Mild (4 - 7 days)	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
	Moderate (7 - 21 days)	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
	Major (21 days +)	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	10	0.6 (0.3 to 1.2)	39.2 (21.1 to 72.8)	20.8
	Tackle 2	12	0.8 (0.4 to 1.3)	47.0 (26.7 to 82.7)	25.0
	Tackle 3	11	0.7 (0.4 to 1.2)	43.1 (23.9 to 77.8)	22.9
	Tackle 4	7	0.4 (0.2 to 0.9)	27.4 (13.1 to 57.5)	14.6
	Tackle 5	8	0.5 (0.3 to 1.0)	31.3 (15.7 to 62.6)	16.7
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 12: Adjustables as the tackler tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Player No.				
6. Stand Off	6	1.2 (0.5 to 2.7)	94.0 (42.2 to 209.2)	12.5
7. Half back	14	2.9 (1.7 to 4.8)	219.3 (129.9 to 370.3)	29.2
9. Hooker	22	4.5 (2.9 to 6.8)	344.6 (226.9 to 523.4)	45.8
13. Loose Forward	6	1.2 (0.5 to 2.7)	94.0 (42.2 to 209.2)	12.5
Forwards	28	5.7 (3.9 to 8.3)	73.1 (50.5 to 105.9)	58.3
Backs	20	4.1 (2.6 to 6.3)	42.8 (27.6 to 66.4)	41.7
Injury Type				
Sprains	11	2.2 (1.2 to 4.0)	43.1 (23.9 to 77.8)	22.9
Strains	8	1.6 (0.8 to 3.3)	31.3 (15.7 to 62.6)	16.7
Lacerations	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
Bruise	15	3.1 (1.8 to 5.1)	58.7 (35.4 to 97.4)	31.3
Fracture	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
Dislocation	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
Cramp	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Concussion	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
Other	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Injury Site				
Head	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.5
Neck	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Shoulder	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.5
Upper Arm	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
Elbow	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.4
Lower Arm	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
Wrist	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
Hand	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
Finger	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.2
Groin	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Quadriceps	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Knee	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.5
Lower Leg	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.3
Ankle	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.3
Injury Region				
Head/Neck	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	14.6
Upper Limb	26	5.3 (3.6 to 7.8)	101.8 (69.3 to 149.5)	54.2
Chest/Back	0	0.0 -	0.0 -	0.0
Lower Limb	15	3.1 (1.8 to 5.1)	58.7 (35.4 to 97.4)	31.3

Table 13: Total Hit Up Forwards tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Injury rate per 1000 Tackle events Rate (95% CI)	%
Total		100	10.3 (8.4 to 12.5)	391.6 (321.9 to 476.4)	100.0
Number of Tacklers					
	1	19	2.0 (1.2 to 3.1)	74.4 (47.5 to 116.6)	19.0
	2	46	4.7 (3.5 to 6.3)	180.1 (134.9 to 240.5)	46.0
	3	30	3.1 (2.2 to 4.4)	117.5 (82.1 to 168.0)	30.0
	4 or more	5	0.5 (0.2 to 1.2)	19.6 (8.1 to 47.0)	5.0
Tackle Height					
	Head/Neck	31	3.2 (2.2 to 4.5)	121.4 (85.4 to 172.6)	31.0
	Shoulder	54	5.5 (4.2 to 7.2)	211.5 (162.0 to 276.1)	54.0
	Mid Torso	45	4.6 (3.4 to 6.2)	176.2 (131.6 to 236.0)	45.0
	Hip / Thigh	19	2.0 (1.2 to 3.1)	74.4 (47.5 to 116.6)	19.0
	Lower Legs	3	0.3 (0.1 to 1.0)	11.7 (3.8 to 36.4)	3.0
Degree of Tackler Position					
	300°-330°	30	3.1 (2.2 to 4.4)	117.5 (82.1 to 168.0)	30.0
	330°-360°	15	1.5 (0.9 to 2.6)	58.7 (35.4 to 97.4)	15.0
	000°-030°	18	1.8 (1.2 to 2.9)	70.5 (44.4 to 111.9)	18.0
	030°-060°	31	3.2 (2.2 to 4.5)	121.4 (85.4 to 172.6)	31.0
	060°-300°	52	5.3 (4.1 to 7.0)	203.6 (155.2 to 267.2)	52.0
Match Time					
	1st Quarter	19	2.0 (1.2 to 3.1)	297.6 (189.8 to 466.6)	19.0
	2nd Quarter	23	2.4 (1.6 to 3.6)	360.3 (239.4 to 542.2)	23.0
	3rd Quarter	27	2.8 (1.9 to 4.0)	422.9 (290.0 to 616.7)	27.0
	4th Quarter	31	3.2 (2.2 to 4.5)	485.6 (341.5 to 690.5)	31.0
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
Defence	0-10	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	6.0
Defence	10-20	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	6.0
Defence	20-30	14	1.4 (0.9 to 2.4)	54.8 (32.5 to 92.6)	14.0
Defence	30-40	13	1.3 (0.8 to 2.3)	50.9 (29.6 to 87.7)	13.0
Defence	40-50	14	1.4 (0.9 to 2.4)	54.8 (32.5 to 92.6)	14.0
Attack	50-40	13	1.3 (0.8 to 2.3)	50.9 (29.6 to 87.7)	13.0
Attack	40-30	16	1.6 (1.0 to 2.7)	62.7 (38.4 to 102.3)	16.0
Attack	30-20	6	0.6 (0.3 to 1.4)	23.5 (10.6 to 52.3)	6.0
Attack	20-10	8	0.8 (0.4 to 1.6)	31.3 (15.7 to 62.6)	8.0
Attack	10-0	3	0.3 (0.1 to 1.0)	11.7 (3.8 to 36.4)	3.0
Attack	In Goal	1	0.1 (0.0 to 0.7)	3.9 (0.6 to 27.8)	1.0
Injury Severity					
	Transient (0 - 4 days)	81	8.3 (6.7 to 10.3)	317.2 (255.1 to 394.4)	81.0
	Mild (4 - 7 days)	13	1.3 (0.8 to 2.3)	50.9 (29.6 to 87.7)	13.0
	Moderate (7 - 21 days)	2	0.2 (0.1 to 0.8)	7.8 (2.0 to 31.3)	2.0
	Major (21 days +)	4	0.4 (0.2 to 1.1)	15.7 (5.9 to 41.7)	4.0
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	19	0.9 (0.6 to 1.4)	74.4 (47.5 to 116.6)	19.0
	Tackle 2	21	1.0 (0.7 to 1.5)	82.2 (53.6 to 126.1)	21.0
	Tackle 3	32	1.5 (1.1 to 2.2)	125.3 (88.6 to 177.2)	32.0
	Tackle 4	19	0.9 (0.6 to 1.4)	74.4 (47.5 to 116.6)	19.0
	Tackle 5	9	0.4 (0.2 to 0.8)	35.2 (18.3 to 67.7)	9.0
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 14: Total Hit Up Forwards tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Position				
8. Prop	31	25.2 (17.8 to 35.9)	485.6 (341.5 to 690.5)	31.0
10. Prop	17	13.8 (8.6 to 22.3)	266.3 (165.5 to 428.4)	17.0
11. second row	22	17.9 (11.8 to 27.2)	344.6 (226.9 to 523.4)	22.0
12. Second row	30	24.4 (17.1 to 34.9)	469.9 (328.6 to 672.1)	30.0
Forwards	100	13.6 (11.2 to 16.5)	261.1 (214.6 to 317.6)	100.0
Injury Type				
Abrasions	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Sprains	14	11.4 (6.8 to 19.2)	54.8 (32.5 to 92.6)	14.0
Strains	25	20.4 (13.8 to 30.1)	97.9 (66.2 to 144.9)	25.0
Lacerations	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Bruise	37	30.1 (21.8 to 41.6)	144.9 (105.0 to 200.0)	37.0
Fracture	3	2.4 (0.8 to 7.6)	11.7 (3.8 to 36.4)	3.0
Dislocation	3	2.4 (0.8 to 7.6)	11.7 (3.8 to 36.4)	3.0
Concussion	8	6.5 (3.3 to 13.0)	31.3 (15.7 to 62.6)	8.0
Other	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.0
Injury Site				
Head	12	9.8 (5.5 to 17.2)	47.0 (26.7 to 82.7)	12.0
Mouth	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Neck	3	2.4 (0.8 to 7.6)	11.7 (3.8 to 36.4)	3.0
Shoulder	12	9.8 (5.5 to 17.2)	47.0 (26.7 to 82.7)	12.0
Upper Arm	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Elbow	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	5.0
Lower Arm	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.0
Wrist	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Hand	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Finger	6	4.9 (2.2 to 10.9)	23.5 (10.6 to 52.3)	6.0
Chest	10	8.1 (4.4 to 15.1)	39.2 (21.1 to 72.8)	10.0
Back	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Groin	7	5.7 (2.7 to 12.0)	27.4 (13.1 to 57.5)	7.0
Hamstring	2	1.6 (0.4 to 6.5)	7.8 (2.0 to 31.3)	2.0
Quadriceps	9	7.3 (3.8 to 14.1)	35.2 (18.3 to 67.7)	9.0
Knee	11	9.0 (5.0 to 16.2)	43.1 (23.9 to 77.8)	11.0
Lower Leg	11	9.0 (5.0 to 16.2)	43.1 (23.9 to 77.8)	11.0
Ankle	5	4.1 (1.7 to 9.8)	19.6 (8.1 to 47.0)	5.0
Toe	1	0.8 (0.1 to 5.8)	3.9 (0.6 to 27.8)	1.0
Injury Region				
Head/Neck	17	13.8 (8.6 to 22.3)	66.6 (41.4 to 107.1)	17.0
Upper Limb	26	21.2 (14.4 to 31.1)	101.8 (69.3 to 149.5)	26.0
Chest/Back	12	9.8 (5.5 to 17.2)	47.0 (26.7 to 82.7)	12.0
Lower Limb	45	36.6 (27.4 to 49.1)	176.2 (131.6 to 236.0)	45.0

Table 15: Hit Up Forwards as the ball carrier tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Total		53	11.0 (8.4 to 14.4)	207.6 (158.6 to 271.7)	53.0
Number of tacklers					
	1	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
	2	21	4.3 (2.8 to 6.7)	82.2 (53.6 to 126.1)	39.6
	3	24	5.0 (3.3 to 7.4)	94.0 (63.0 to 140.2)	45.3
	4 or more	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
Tackle Height					
	Head/Neck	27	5.6 (3.8 to 8.2)	105.7 (72.5 to 154.2)	50.9
	Shoulder	31	6.4 (4.5 to 9.1)	121.4 (85.4 to 172.6)	58.5
	Mid Torso	29	6.0 (4.2 to 8.6)	113.6 (78.9 to 163.4)	54.7
	Hip / Thigh	16	3.3 (2.0 to 5.4)	62.7 (38.4 to 102.3)	30.2
	Lower Legs	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
Degree of Tackler Position					
	300°-330°	27	5.6 (3.8 to 8.2)	105.7 (72.5 to 154.2)	50.9
	330°-360°	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	17.0
	000°-030°	13	2.7 (1.6 to 4.6)	50.9 (29.6 to 87.7)	24.5
	030°-060°	22	4.6 (3.0 to 6.9)	86.2 (56.7 to 130.8)	41.5
	060°-300°	29	6.0 (4.2 to 8.6)	113.6 (78.9 to 163.4)	54.7
Match Time					
	1st Quarter	12	2.5 (1.4 to 4.4)	188.0 (106.7 to 331.0)	22.6
	2nd Quarter	13	2.7 (1.6 to 4.6)	203.6 (118.2 to 350.7)	24.5
	3rd Quarter	11	2.3 (1.3 to 4.1)	172.3 (95.4 to 311.1)	20.8
	4th Quarter	17	3.5 (2.2 to 5.7)	266.3 (165.5 to 428.4)	32.1
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
	0-10	0	0.0 -	0.0 -	0.0
	10-20	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	5.7
	20-30	11	2.3 (1.3 to 4.1)	43.1 (23.9 to 77.8)	20.8
	30-40	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	13.2
	40-50	11	2.3 (1.3 to 4.1)	43.1 (23.9 to 77.8)	20.8
Attack	50-40	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
	40-30	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	13.2
	30-20	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
	20-10	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	9.4
	10-0	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
	In Goal	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	1.9
Injury Severity					
	Transient (0 - 4 days)	38	7.9 (5.7 to 10.8)	148.8 (108.3 to 204.5)	71.7
	Mild (4 - 7 days)	10	2.1 (1.1 to 3.8)	39.2 (21.1 to 72.8)	18.9
	Moderate (7 - 21 days)	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
	Major (21 days +)	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	5.7
Tackle no					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	12	2.5 (1.4 to 4.4)	47.0 (26.7 to 82.7)	22.6
	Tackle 2	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	17.0
	Tackle 3	19	3.9 (2.5 to 6.2)	74.4 (47.5 to 116.6)	35.8
	Tackle 4	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	17.0
	Tackle 5	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 16: Hit Up Forwards as the ball carrier tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 Tackle events Rate (95% CI)	Tackle events Rate (95% CI)	%
Player Position.				
8. Prop	17	13.8 (8.6 to 22.3)	266.3 (165.5 to 428.4)	32.1
10. Prop	9	7.3 (3.8 to 14.1)	141.0 (73.4 to 270.9)	17.0
11. second row	14	11.4 (6.8 to 19.2)	219.3 (129.9 to 370.3)	26.4
12. Second row	13	10.6 (6.1 to 18.2)	203.6 (118.2 to 350.7)	24.5
Forwards	53	7.2 (5.5 to 9.4)	138.4 (105.7 to 181.1)	100.0
Injury Type				
Sprains	12	2.5 (1.4 to 4.4)	47.0 (26.7 to 82.7)	22.6
Strains	12	2.5 (1.4 to 4.4)	47.0 (26.7 to 82.7)	22.6
Bruise	20	4.1 (2.7 to 6.4)	78.3 (50.5 to 121.4)	37.7
Fracture	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	5.7
Concussion	6	1.2 (0.6 to 2.8)	23.5 (10.6 to 52.3)	11.3
Injury Site				
Head	6	1.2 (0.6 to 2.8)	23.5 (10.6 to 52.3)	11.3
Mouth	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
Neck	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	1.9
Shoulder	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	5.7
Wrist	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	1.9
Chest	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
Back	1	0.2 (0.0 to 1.5)	3.9 (0.6 to 27.8)	1.9
Groin	6	1.2 (0.6 to 2.8)	23.5 (10.6 to 52.3)	11.3
Hamstring	2	0.4 (0.1 to 1.7)	7.8 (2.0 to 31.3)	3.8
Quadriceps	8	1.7 (0.8 to 3.3)	31.3 (15.7 to 62.6)	15.1
Knee	8	1.7 (0.8 to 3.3)	31.3 (15.7 to 62.6)	15.1
Lower Leg	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	13.2
Ankle	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
Injury Region				
Head/Neck	9	1.9 (1.0 to 3.6)	35.2 (18.3 to 67.7)	17.0
Upper Limb	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	7.5
Chest/Back	5	1.0 (0.4 to 2.5)	19.6 (8.1 to 47.0)	9.4
Lower Limb	35	7.2 (5.2 to 10.1)	137.1 (98.4 to 190.9)	66.0

Table 17: Hit Up Forwards as the tackler tackle injuries by tackle number, tackle height, degree of tackler position, match time, field position, injury severity and tackle number per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

		No.	Injury rate per 1000 tackle events Rate (95% CI)	Injury rate per 1000 match hours Rate (95% CI)	%
Total		47	9.6 (7.2 to 12.7)	184.1 (138.3 to 245.0)	47.0
Tackler No.					
	1	15	3.1 (1.8 to 5.1)	58.7 (35.4 to 97.4)	31.9
	2	25	5.1 (3.4 to 7.5)	97.9 (66.2 to 144.9)	53.2
	3	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
	4 or more	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Tackle Height					
	Head/Neck	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.5
	Shoulder	23	4.7 (3.1 to 7.0)	90.1 (59.9 to 135.5)	48.9
	Mid Torso	16	3.3 (2.0 to 5.3)	62.7 (38.4 to 102.3)	34.0
	Hip / Thigh	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
	Lower Legs	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Degree of Tackle Position					
	300°-330°	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
	330°-360°	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
	000°-030°	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.6
	030°-060°	9	1.8 (1.0 to 3.5)	35.2 (18.3 to 67.7)	19.1
	060°-300°	23	4.7 (3.1 to 7.0)	90.1 (59.9 to 135.5)	48.9
Match Time					
	1st Quarter	7	1.4 (0.7 to 3.0)	109.6 (52.3 to 230.0)	14.9
	2nd Quarter	10	2.0 (1.1 to 3.8)	156.6 (84.3 to 291.1)	21.3
	3rd Quarter	16	3.3 (2.0 to 5.3)	250.6 (153.5 to 409.1)	34.0
	4th Quarter	14	2.9 (1.7 to 4.8)	219.3 (129.9 to 370.3)	29.8
Field Position					
Defence	In Goal	0	0.0 -	0.0 -	0.0
Defence	0-10	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
Defence	10-20	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Defence	20-30	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Defence	30-40	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
Defence	40-50	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Attack	50-40	9	1.8 (1.0 to 3.5)	35.2 (18.3 to 67.7)	19.1
Attack	40-30	9	1.8 (1.0 to 3.5)	35.2 (18.3 to 67.7)	19.1
Attack	30-20	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.5
Attack	20-10	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Attack	10-0	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Attack	In Goal	0	0.0 -	0.0 -	0.0
Injury Severity					
	Transient (0 - 4 days)	43	8.8 (6.5 to 11.8)	168.4 (124.9 to 227.1)	91.5
	Mild (4 - 7 days)	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
	Moderate (7 - 21 days)	0	0.0 -	0.0 -	0.0
	Major (21 days +)	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Tackle no.					
	Tackle 0	0	0.0 -	0.0 -	0.0
	Tackle 1	7	0.4 (0.2 to 0.9)	27.4 (13.1 to 57.5)	14.9
	Tackle 2	12	0.8 (0.4 to 1.3)	47.0 (26.7 to 82.7)	25.5
	Tackle 3	13	0.8 (0.5 to 1.4)	50.9 (29.6 to 87.7)	27.7
	Tackle 4	10	0.6 (0.3 to 1.2)	39.2 (21.1 to 72.8)	21.3
	Tackle 5	5	0.3 (0.1 to 0.8)	19.6 (8.1 to 47.0)	10.6
	Tackle 6	0	0.0 -	0.0 -	0.0
	Incomplete Tackle	0	0.0 -	0.0 -	0.0

Table 18: Hit Up Forwards as the tackler tackle injuries by player position, injury type and injury region per 1000 tackle events and 1000 match hours with 95% confidence intervals and percentages.

	No.	Injury rate per 1000 tackle events Rate (95% CI)	Injury rate per 1000 match hours Rate (95% CI)	%
Player No.				
8. Prop	14	2.9 (1.7 to 4.8)	219.3 (129.9 to 370.3)	29.8
10. Prop	8	1.6 (0.8 to 3.3)	125.3 (62.7 to 250.6)	17.0
11. second row	8	1.6 (0.8 to 3.3)	125.3 (62.7 to 250.6)	17.0
12. Second row	17	3.5 (2.2 to 5.6)	266.3 (165.5 to 428.4)	36.2
Forwards	47	9.6 (7.2 to 12.7)	122.7 (92.2 to 163.3)	100.0
Injury Type				
Abrasions	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Sprains	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Strains	13	2.6 (1.5 to 4.6)	50.9 (29.6 to 87.7)	27.7
Lacerations	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Bruise	17	3.5 (2.2 to 5.6)	66.6 (41.4 to 107.1)	36.2
Dislocation	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Concussion	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Other	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Injury Site				
Head	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
Neck	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Shoulder	9	1.8 (1.0 to 3.5)	35.2 (18.3 to 67.7)	19.1
U Arm	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Elbow	5	1.0 (0.4 to 2.4)	19.6 (8.1 to 47.0)	10.6
L Arm	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Wrist	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Hand	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Finger	2	0.4 (0.1 to 1.6)	7.8 (2.0 to 31.3)	4.3
Chest	6	1.2 (0.5 to 2.7)	23.5 (10.6 to 52.3)	12.8
Back	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Groin	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Quadriceps	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Knee	3	0.6 (0.2 to 1.9)	11.7 (3.8 to 36.4)	6.4
Lower Leg	4	0.8 (0.3 to 2.2)	15.7 (5.9 to 41.7)	8.5
Ankle	1	0.2 (0.0 to 1.4)	3.9 (0.6 to 27.8)	2.1
Injury Region				
Head/Neck	8	1.6 (0.8 to 3.3)	31.3 (15.7 to 62.6)	17.0
Upper Limb	22	4.5 (2.9 to 6.8)	86.2 (56.7 to 130.8)	46.8
Chest/Back	7	1.4 (0.7 to 3.0)	27.4 (13.1 to 57.5)	14.9
Lower Limb	10	2.0 (1.1 to 3.8)	39.2 (21.1 to 72.8)	21.3