Injury incidence and physiological requirements of a domestic amateur women's rugby union team in New Zealand

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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 5 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 contributions of 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

29th January 2021

Abstract

Women's rugby union has undergone a period of transition to become, reportedly, the fastest growing form of the game worldwide. Although the game is played nationally and internationally, it was not until 1991 that the first Rugby World Cup for women (RWC(W)) was held. Despite increased popularity and growth, the published studies investigating the epidemiological aspects of match and training in women's rugby union is limited. Of the published studies to date, none have reported on aspects related to women's rugby union participants in New Zealand. Therefore, the overall aim of this thesis was to explore and document the epidemiology of injuries in an amateur women's rugby union team in New Zealand. As fatigue has been indicated as a possible injury risk factor, the physiological demands of match participation in amateur women's rugby union were also assessed.

Specific aims of the thesis were (1) The identification of the physiological and heart-rate demands of match participation for amateur women rugby union players; (2) The identification of the most common site, type, severity, and frequency of injuries that occur to women in rugby union training and match related activities (Systematic Review); (3) The identification of the most common site, type, severity, and frequency of injuries that occur to women in rugby union training and match related activities in New Zealand. The methodological approaches utilised in this thesis included an epidemiological analysis (Chapter 3), and a prospective observational cohort analysis (Chapters 2, 4 and 5).

In measuring the movement demands of amateur domestic women's rugby union (Chapter 2), player movements were monitored using microtechnology GPS devices. Players' heart rates were also continuously monitored during match participation using a portable monitor. A mean total distance per match of 3,546.6 ±1,329.2 m was recorded

over 28 matches. This resulted in a mean distance of 38.3 ±13.7 m·min^{-1} which was less than women's football (79.3 to 118.0 m·min^{-1}: mean 101.0 ±11.9 m·min^{-1}), hockey (79.0 to 115.0 m·min^{-1}: mean: 98.5 ±15.6 m·min^{-1}) and women's elite rugby union (54.8 to 68.0 m·min^{-1}; mean: 61.4 ±9.3 m·min^{-1}). Although Forwards recorded a lower total distance (3,409.7 ±1,201.9 m vs. 3,692.3 ±1,440.5 m) and m·min-^{1} (36.7 ±12.4 m·min-^{1} vs. 40.0 ±14.9 m·min^{-1}) than Backs, they had a similar player-load (PL) (3.8 ±1.3 au·min^{-1} vs. 3.9 ±1.4 au·min^{-1}), PL 2-dimensional (2.9 ±1.0 au·min^{-1} vs. 2.9 ±1.1 au·min^{-1}), PL Forward (1.8 ±0.7 au·min^{-1} vs. 1.7 ±0.7 au·min^{-1}), PL side (1.9 ±0.7 au·min^{-1} vs. 1.9 ±0.7 au·min^{-1}) and PL vertical (2.9 ±1.0 au·min^{-1} vs. 3.0 ±1.2 au·min^{-1}) when compared to Backs. Forwards recorded a higher maximum heart rate than Backs (191 b·min^{-1} vs. 188 b·min^{-1}), indicating a higher cardiovascular stress and physiological strain for Forwards compared with Backs. The results of this study suggested that the physical and physiological profile of the playing group, at the amateur domestic level of women's rugby union, were quite similar and may be suggestive of generalised, rather than specialised, training regimes that fail to prepare players for the position specific demands needed at higher levels of competition.

The systematic review (Chapter 3) of literature reporting on women's rugby union incorporated both rugby-15 and rugby-7s match and training related published studies. Only 10 articles identified through systematic searches of PubMed, SPORTDiscus, Web of Science Core Collection, Scopus, CINAHL(EBSCO) and ScienceDirect databases using keywords were included in the review. The incidence of injuries in rugby-15s varied from 3.6 (95% CI: 2.5-5.3) per 1,000 match-hr (including training and games) to 37.5 (95% CI: 26.5-48.5) per 1,000 match-hr, with a pooled incidence of 19.6 (95% CI: 17.7-21.7) per 1,000 match-hr. For rugby-7s, the injury incidence varied from 46.3 (95% CI: 38.7-55.4) per 1,000 match-hr to 95.4 (95% CI: 79.9-113.9) per 1,000 match-hr with a pooled incidence of 62.5 (95% CI: 54.7-70.4) per 1,000 player-hr. The tackle was the most commonly reported injury cause, with the ball carrier recording more injuries than the tackler at the collegiate, and RWC(W) levels of participation. Concussions and sprains/strains were the most commonly reported injuries at the collegiate level of participation. The incidence of injury in women's rugby-15s and rugby-7s was lower than in men's professional rugby-15s and rugby-7s competitions, but similar to male youth rugby-15s players. Differences in reporting methodologies limited comparisons of results between studies. Of note, the systematic review failed to identify any New Zealand based studies in women's rugby union.

A key finding of the systematic review was that there were no women's rugby union training-specific studies identified. By conducting a prospective cohort observational study on the training sessions of an amateur women's rugby union team, over two-years (Chapter 4), it was identified that the total injury incidence was 11.4 (95% CI: 8.3 to 15.6) per 1,000 training hrs. There were 12 injuries that resulted in a time-loss injury incidence of 3.6 (95% CI: 2.0 to 6.3) per 1,000 training-hrs. The tackle was the most common cause for total (3.0 [95% CI: 1.6 to 5.6] per 1,000 training-hrs.) injuries, but collisions (1.5 [95% CI: 0.6 to 3.6] per 1,000 training-hrs.) with the ground or another person were the most common cause for time-loss injuries. The training injuries occurred most often to the lower limb and during the latter part of training sessions. These injuries were mostly minor in nature, resulting in minimal time-loss away from training. The time-loss injury incidence (3.6 [95% CI: 2.0 to 6.3] per 1,000 training-hrs.) for the amateur women's rugby 15s team players was higher than that reported for National (1.2 [95% CI: 0.4 to 3.1] per 1,000 training-hrs.) and RWC(W) (0.2 [95% CI: 0.0 to 2.2] to 3.0 [95% CI: 1.8 to 5.0] per 1,000 training-hrs.) competitions.

The incidence of match injuries (Chapter 5) was conducted utilising a prospective cohort observational study on an amateur women's rugby union, over two consecutive seasons. A total of 138 injuries were recorded resulting in an injury incidence of 247.0 (95% CI: 209.1 to 291.9) per 1,000 match-hrs. A total of 57 injuries resulted in a time-loss injury incidence of 102.0 (95% CI: 78.7 to 132.3) per 1,000 match-hrs. Although Forwards (261.8 [95% CI: 209.7 to 326.9] per 1,000 match-hrs.) recorded a higher total injury incidence than Backs (230.2 [95% CI: 178.7 to 296.4] per 1,000 match-hrs.), Backs recorded higher time-loss injury incidence (107.4 [95% CI: 74.2 to 155.6] per 1,000 match-hrs.) than Forwards (97.3 [95% CI: 67.6 to 140.1] per 1,000 match hrs). The lower limb sustained the highest injury incidence, with the knee having the greatest proportion of these injuries for both total (48.3 [95% CI: 33.1 to 70.5] per 1,000 match-hrs.) and time-loss (21.5 [95% CI: 12.2 to 37.8] per 1,000 match-hrs.) injuries. Sprains and strains recorded the highest incidence of all the injuries recorded and the lower limb body region recorded the most days lost and had the highest mean days lost per injury. The incidence of concussion (16.1 [95% CI: 8.4 to 31.0] per 1,000 match-hrs.) over the study was higher than previous studies reporting on women's rugby union at the RWC(W) (3.5 [95% CI: 1.7 to 7.0] per 1,000 match hrs) and collegiate rugby union (1.6 [95% CI: 1.1 to 2.3] per 1,000 player match-hrs.) levels of participation. The tackle was recorded as being the most common injury cause and this was expected. Upon further analysis, it was identified that the action of being the ball carrier, rather than the tackler, during a tackle situation was associated with a notably higher injury incidence than any other match event. Future research is warranted to identify risk factors involved in the tackle unique to women participants.

This PhD thesis has contributed knowledge regarding the incidence of injuries in amateur women rugby union players in New Zealand which has not been undertaken before. In addition, this PhD thesis has contributed further knowledge regarding the physiological demands of amateur women's rugby union match participation (see Chapter 6).

"When truth is buried underground it grows, it chokes, it gathers such an explosive force that on the day it bursts out, it blows up everything with it. The truth is on the march, and nothing shall stop it."

Emile Zola, "J'Accuse!" L'Aurore, Jan. 13, 1898

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I would like to thank my supervisors Matt Barnes and Andy Foskett for their time and input into the production of the series of studies in this thesis.

To my long-time friend, colleague and 'brother' Trevor Clark. Always standing beside me, battling with me, and looking at ways to improve player health.

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And lastly to my mother Kathleen Sutherland (1943-2019). Sadly, after starting this PhD mum lost the battle of life and we lost a caring loving soul. Mum was my inspiration, rock, and shoulder to cry on. She is sadly missed and much loved. Rest now mum, it is our turn to carry your flame.

Ethical approval

Ethical approval for this research was granted by:

1. Health and Disability Ethics Committee: 18/STH/224/AM01
2. Auckland University of Technology Ethics Committee: 16/35

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Chapter 1: General Introduction

Sport and exercise are important to assist with both short- and long-term physical and psychological wellbeing.[8, 237, 241] The health benefits associated with participating in sport and exercise activities are well known and include improved cardiovascular function, metabolic and aerobic fitness, and a reduced risk of illness and disease , including colon cancer, obesity, diabetes mellitus and, in some cases, reduced mortality.[8, 163, 248, 249] As a result, many people undertake a variety of sports and exercise activities for pleasure, recreation, competition and socialisation, as well as to assist with an improvement in their health.[8, 241]

However, sport and exercise also carry a risk for injuries to occur. Injuries from sport and exercise participation can be costly in terms of loss of participation, financial loss due to inability to work and the cost's associated with rehabilitation from the injury and, in some cases, these can lead to permanent disability.[8, 241] In order to assist with the identification and management of the injuries that occur from a sport or exercise activity, injury surveillance is fundamental.[91, 96, 310] Injury surveillance also assists with the provision of information regarding the risk of these injuries to the participants, as well as providing the administrative or regulatory bodies with the necessary evidence in order for them to make associated risk mitigation strategies.[264]

Injury identification and prevention

The most commonly cited sports injury surveillance framework is the sequence of injury prevention model.[310] Built on previous public health approaches,[91] the sequence of prevention (see Figure 1) consists of four key steps towards sports injury prevention.

When this was first published, the aspects of the first (extent and severity of injury) and second (aetiology) stages of the four-stage process were the primary focus in the development towards injury prevention programs.

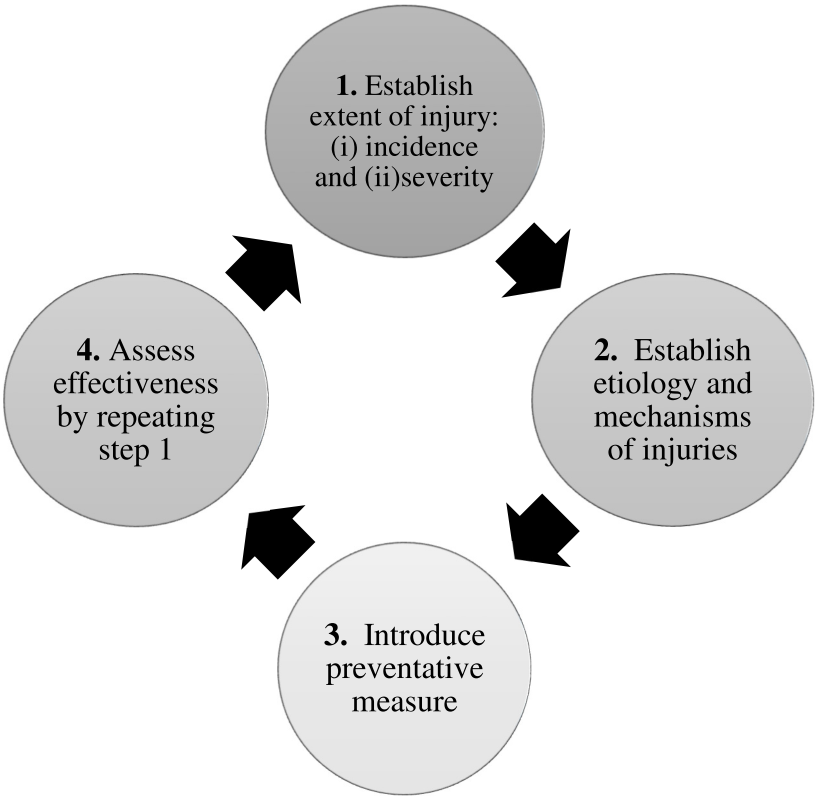

Figure 1: The four steps in the sequence of prevention of sports injuries[308-310]

More recently, there has been an increase in epidemiological studies contributing information to the first two steps of the sequence of prevention of the sports injury model. In particular this has been undertaken to:

(1) Establish the extent of the injury problem (injury incidence); and

(2) Establish the aetiology and mechanisms of injury (mechanisms involved and factors provoking the injury).[47]

A critical step in the sequence of prevention of sports injuries is the establishment of the cause of the injury or the injury risk.[9] Injury risk has been traditionally divided into two main categories: (1) Intrinsic (internal) participant-related risk factors and (2) Extrinisic (external) enviromental risk factors[215, 284, 310, 317] (see Table 1 for an example of some risk factors). An important point here is that these risk factors can be further divided into modifiable and non-modifiable factors. Factors such as age,[240] sex,[240] injury history,[138, 203, 305] sport[154] and the level of participation[240] are non-modifiable risk factors and provide minimal avenues for injury prevention but can have an influence on the modifiable risk factors.[83]

Table 1: Some intrinsic (personal) and extrinsic (external) risk factors that may play a part in sports injuries.[215, 284, 310, 317]

Intrinsic Risk Factors	Extrinsic Risk Factors
Physical characteristics	Exposure
Age	Type of sports
Sex	Playing time
Somatotype	Position in the team
Body size	Level of competition
Previous injury	Warm-up
	Personal equipment
Physical fitness	Inexperience
Joint mobility	Training
Muscle tightness	Coaching
Ligamentous laxity	Refereeing
Malalignment of lower extremities	Control of game
Dynamic strength	Opponents
Static strength	Foul play
Skill level	Opponent's physique
Psychological characteristics	Environment
Psychosocial characteristics	Type and condition of playing surface
Skill level	Weather conditions
Willingness to take risks	Time of day
Interaction with other players	Time of season
Experience of sport	Equipment
	Protective equipment
	Footwear
	Orthotics

As a result of an individual's predisposition to injury, extrinsic factors (exposure to factors of risk) (see Table 1) could exert an influence on this predisposition, resulting in an injury occurring. Given this predisposition, the injury that occurs is a result of a further "initiating event". This would require an event to occur where the force is transferred to the body. The initiating event may be observed and the resulting injury witnessed, but little attention may be given to the factors that are more distant from the event, e.g. the susceptibility of the individual to the injury caused by intrinsic risk factors.[137]

To understand the importance of the problem, it is necessary to know the injury profile for the sporting activity, such as the injury frequency (i.e. the number of injuries per 1,000 hours of training or match activities), location of the injury site (i.e. anatomical body site), the severity of the injury (i.e. transient, mild, moderate or severe depending on injury definition) and the typology of the injuries that occur.[97, 98] Although widely published, the sequence of prevention of sports injuries model has been clearly demonstrated[40, 91, 211, 290] to be of limited use for sports, as well as general injury prevention, with more recent models being developed.[231, 232]

Building on the van Mechelen model,[310] a linear multifactorial model for athletic injury etiology was developed.[231] Although an advancement of the sequence of prevention model, the multifactorial model of athletic injury was reportedly too simplistic and did not reflect the true nature of injury in sport, account for what happens after the injury has occurred, how the participant may return to sport and how the susceptibility to injury changes.[137] As a result, a cyclical operational model for the investigation of contact sports injuries was published[137] and this model recognised that sports injury is not an endpoint, and that returning sports participants will have different intrinsic and extrinsic risk factors as a result of the previous injury they incurred. A further development on the cyclical operational model was published in 2007.[232] The dynamic, recursive model of etiology in sport injury[232] enabled the sports participant to cycle through the model repeatedly irrespective of exposure and risk factors.

In 2006, the Translating Research into Injury Prevention Practice (TRIPP) framework[91] was developed and this emphasised the key role of the implementation aspects of achieving real-world injury prevention. In adding on to the van Mechelen model, the TRIPP framework added additional steps to include a description of the intervention and evaluation of the intervention via 'real-world' analytics.[91] Although a development on the 'sequence of prevention', there were still limitations and subsequent injury-prevention models were developed utilising linear,[102, 232] reductionist,[20] generic,[279] operational steps[253, 279] and player workload[323] approaches. Although each of these models has its place within the sports-injury prevention perspective, the applicability and relevance of these models are context dependent, as some of the models developed were geared towards developing etiological theory[20, 232] or the conducting of injury prevention research.[91, 310] What has been identified for these models is the lack of risk management approaches towards injury prevention for those working at the 'coalface'.[76, 96]

More recently, a cyclical injury prevention model has been produced that is directly applicable to team sport specific contexts and acknowledges real-world implementation challenges.[245] The Team-sport Injury Prevention (TIP)[246] (see Figure 2) is a continuous cycle model consisting of three key phases that incorporates important implementation aspects of previous models[91, 310] and is consistent with a risk management approach.[96, 102]

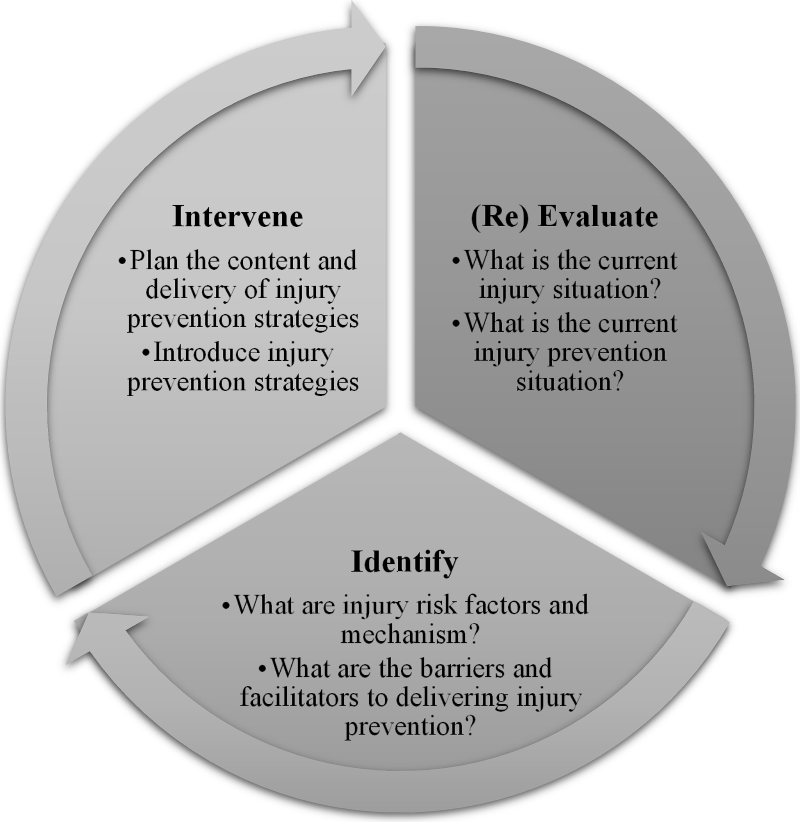

Figure 2: The Team-sport Injury Prevention (TIP) cycle[246]

The first phase of the TIP model[246] is '(Re) Evaluate'. This requires the assessment (or reassessment) of the current 'state-of-play' of the environment that the model is being applied to. The second phase of the TIP model[246] is 'Identification'. Once the '(Re) Evaluate' phase is completed, then the 'Identification' phase undertakes to explore the risk factors and mechanisms underpinning the injuries that were identified. This would also enable the identification of any facilitators and barriers to implementing injury prevention strategies.[222, 247] As part of this phase, it is important to appreciate the multifactorial nature of injury epidemiology,[20] consider the degree to which the identified injuries can be modified[246] and to assess injury risk at an individual level.[323]

The third phase of the TIP model[246] is 'Intervention'. This involves the planning of the content and delivery of the injury prevention strategies by taking into consideration injury risk factors, implementation barriers and facilitators, previous published research and experience of the people carrying out the implementation.[77, 253] This may require a multifactorial approach towards the 'Intervention' and typically involves multiple preventative strategies (e.g. recovery strategies, load management etc.). Once this is underway, the model cycles into '(Re) Evaluate' where the metrics identified (e.g. injury incidence) will require ongoing evaluation and assessment.

Research on women in sport.

In 2017, an article titled "*Sports, exercise and the menstrual cycle: Where is the research?*" was published[38] highlighting the under-representation of women included in sport and exercise medicine research. It was identified that the complexities of the menstrual cycle were the major barrier to the inclusion of women in sport and exercise medicine research.[38] Underlying this barrier was the belief that females were physiologically variable and, therefore, utilising males in sport and exercise medicine research enabled more meaningful results with fewer participants and less funding.[87] Simply put, males were cheaper and easier to work with and "women were just assumed to be… little men".[250]

Recently, there has been a call for the support of future translational research for females in sport.[65, 87] This has occurred as a result of the exponential rise in the professionalism and profile of females participating in sporting activities.[92] This changing horizon for females in sport has identified that there is a short fall in the available sports science that practitioners utilise to apply evidence-based approaches.[85] These evidence-based approaches are utilised in order to accomplish optimal athlete performance and well-being, through the application of research to the real world.[85] Although more females are being represented in the research literature, this is often at the recreational level of participation.[87] As a result, the ability to adopt and apply evidenced-based research to female sports participants is limited.[87]

The traditional approach of applying evidence derived from males to females is concerning, given the biological differences that exists between the sexes.[86, 87] Likewise, the development of evidence for sports performance and injury reduction for females is also a challenge, given the logistical and methodological frameworks required.[86, 162] Changes in hormone concentrations throughout the menstrual cycle,[233] combined with different physiological and biomechanical profiles of females[162] may partially account for the lack of efficacy and effectiveness of interventions applied to females using research conducted on male athletes. As a result, it has been recommended that different performance, nutritional, recovery and injury prevention strategies are required for female sports participants.[87]

Another aspect to consider is the context and environment available for female sports participants, as what occurs in the male version of the game may not be the most appropriate for women.[87] An example of this are the differences in the available resources for women in sport, such as equipment, and professional sports science and medical personnel; this is mainly due to differences in funding provisions. As such, there is a need for research that specifically focuses on females in sport. This should aim to provide a better understanding of aspects such as physical qualities of players, match characteristics, injury and recovery profiles and physiological requirements in females, as they may be different to that of male athletes in the same sporting context.

To illustrate the need for such research, in conducting a review of the available research of females in sport, it has been reported that by using the keywords “injury” and “rugby” and “female” for the previous 10-year period, 196 articles were retrieved.[87] However, by replacing “male” for “female” there were 602 articles retrieved.[87] Due to the fewer female specific studies, there is a need to start with descriptive research in order to understand the current level of performance within female sport.[87] Thus the need for ongoing research in women’s rugby union is warranted.

Women’s rugby union

The game of rugby union can be traced back to an English-American clergyman named William Webb-Ellis who, in 1823, is reported to have picked up the ball and ran with it during an English school game of football at Rugby School in Warwickshire, England.[1, 36] Since then, the game has evolved into a popular international sport, with more than three million people in over 100 countries, across five continents playing the game annually.[36] The first official game of rugby union in New Zealand reportedly took place in Nelson in 1870 and was played under the rules of British Rugby Football.[68] The popularity of rugby union rapidly grew and by 1905 was being hailed as New Zealand’s ‘national’ sport for males.[68]

Although rugby union is very popular among males globally, participation by women has not been as successful, despite several attempts worldwide since 1893.[68] Attempts to establish women's rugby union in New Zealand were scoffed at and condemned, however spectacle games began to emerge, and these became more prevalent during the First World War.[68] Despite attempts to affiliate women's rugby teams with their male counterparts, this was met with medicalised resistance and moral concerns that women participating in rugby union activities would expose them to 'organic weaknesses and diseases' that are likely a result from strenuous exercise of a 'masculine character'.[68] As rugby union requires players to be exposed to repeated high-intensity activities (e.g. running, tackling, rucks, mauls, passing and sprinting), interspersed with short bouts of low intensity activity (e.g. jogging and walking),[36, 80-82] repetitive physical collisions and tackles are common. These repetitive exposures to high forces can place adverse stresses on the body,[15, 23, 33, 58, 80, 127] which results in an increased risk of musculoskeletal injuries occurring.[23, 58, 80, 127]

It was not until the 1960's that women's rugby union began to take shape and, in 1990, the first women's international tournament occurred in New Zealand. This lead to the establishment of the Women's International Rugby Board (WIRB) in 1988[329] and the development of the RWC(W) in 1991. However, the International Rugby Board (now World Rugby) did not officially recognise women's participation until 1996 when they established a Women's Advisory Committee. In 1998, the third Rugby World Cup for women was officially sanctioned and in 1999 the women's Five Nations competition was established in the Northern Hemisphere.[255] Women's rugby union was now becoming more widely accepted and, despite some setbacks, has gone on to become one of the fastest growing areas of growth in the sport, with females now accounting for over a quarter of players globally.[205] Despite the rapid growth of women's rugby union, the number of published studies reporting on match and training activities remains low, when compared with data on male rugby participation.

The concept of women playing in contact sports has traditionally been seen as being amateur and participation has necessitated that women partake in these activities while still maintaining their normal work/family life.[68] This can be observed with women players trying to manage their parenting, employment and sporting demands, resulting in a decreased ability to train appropriately. In addition to this, there is a paucity of knowledge available on the physiological demands of women's rugby union, how to optimise physical fitness in women rugby union players and to what extent aerobic power, speed, muscle strength and power should be trained both preseason and in competition.[143]

As well as biomechanical factors that differ between the sexes, females reportedly have lower physiological capacity (e.g. reduced speed and less agility, lower muscular power, lower estimated maximal aerobic power) when compared with males, placing them at a higher injury risk.[196] As well, there is typically only a single competition or 'grade' available for participation, meaning players of varying experience, ability and level of conditioning and maturity levels may be competing against each other.[264]

Additionally, it has been suggested that weaker neck muscles in females puts them at greater risk of sustaining a sports-related concussion, as they have less protection against a potentially concussive blow.[273] One study revealed sex differences in neuroanatomy;[75] reporting smaller axonal diameter in female brains making them more susceptible to damage during injury. It has also been suggested that female athletes are more honest and more likely to report their concussion.[41, 62] Further, a growing body of evidence[16, 168, 226, 303] shows that following sports-related concussion female athletes experience greater symptom severity and take longer to recover than male athletes.

Movement demands and injury incidence.

The risk of an injury in field-based contact sports may be associated with training and match loads.[56, 63, 158] For example, at the professional levels of competition, the injury risk to rugby union players in the subsequent week increased linearly with the weekly session rating of perceived exertion (sRPE), training load and absolute change in weekly training load.[63] Although there have been studies reporting on injury risk and physical workload in Australian Football[56, 280] and elite rugby league,[112, 113, 115] only one rugby union study[12] has reported on movement demands and injury characteristics; however this was undertaken with under 20 yr. old male rugby union players. Despite these studies, there is a paucity of studies[25, 44, 297, 314] reporting on the movement demands of women's rugby union and these have varied with the methodological approaches. In addition, there are no papers reporting on the movement demands and heart rates of amateur domestic women rugby union players and none at any level on women rugby union players in New Zealand.

A need to explore and understand.

A greater understanding of the true incidence of the injuries that occur in women's rugby union match and training activities, and the underlying mechanisms, is needed to inform effective sex specific preventative interventions. This highlights a further opportunity to improve the care and recovery of women rugby union players to ensure a safe and sustained return to sport.

As previously mentioned, the recently published cyclical injury prevention model, the TIP, is directly applicable to team sport specific contexts and acknowledges real-world implementation challenges.[245] In terms of women's rugby union, the first phase of TIP can be focused on evaluating the type, site, incidence and severity/burden of injuries that can occur from participation in rugby union activities. In revieweing the published literature,[188] it was reported that, although there is a body of literature on women's rugby union, there is a paucity of studies specifically looking at women's rugby union injuries, and that there are no studies specifically undertaken on amateur women's rugby union injuries in New Zealand. Consequently, as there are no studies reporting on women's rugby union injuries or activities in New Zealand, the remaining phases of the TIP model cannot be completed. As a result, the start point for the identification of the current injury situation in amateur women's rugby union activities in New Zealand requires a fresh approach.

Additionally, to identify the influence training and match activities have on stress, recovery and injury incidence, an understanding of the physiological and movement demands of amateur women's rugby union in New Zealand is required. Such information can also be used to establish sport specific training to optimise performance and reduce injuries in women's rugby union.

Purpose of the research

The overall aim of this research is to quantify the movement demands of match participation and the injury incident and burden in an amateur women's rugby team in New Zealand.

The specific research questions were:

1. What are the movement activities and physiological responses of amateur women's rugby union?
2. What is the epidemiology of injury in women's rugby union?
3. What is the incidence, site, type, and timing of training injuries in amateur women's rugby union?
4. What is the incidence, site, type, and timing of match injuries in amateur women's rugby union?

These questions were identified to address the gap in current literature and to establish a baseline of what is occurring in amateur women's rugby union in New Zealand. The production of the literature review provides wider context and allows for a comparison between countries and levels of participation. Although the ability to undertake this research at a national level, using a greater number of women rugby union teams, would provide for a methodologically stronger dataset, the ability to conduct research of this scope and ensure reliability was limited and out of the available resources to the student. It was decided to undertake this research at a local domestic amateur club and to establish a benchmark for which future studies can be compared to.

Structure of the thesis

The literature review (Chapter 3) identified areas that have not been previously reported on and this assisted in the formulation of the structure of the thesis (see Figure 3). The thesis consists of four chapters reporting results from data analysis that culminates in an overall discussion (Chapter 6). Chapters 2 to 5 have been submitted and/or have been accepted for publication or have been published in peer reviewed journals. As such, international peer reviewed feedback has been received and taken into consideration and each chapter is presented in the wording of the journal. As a result, there is some repetition in the introduction and methods between some of these chapters. The references are not included at the end of each chapter, rather an overall reference list from the entire thesis has been collated at the end of the final chapter.

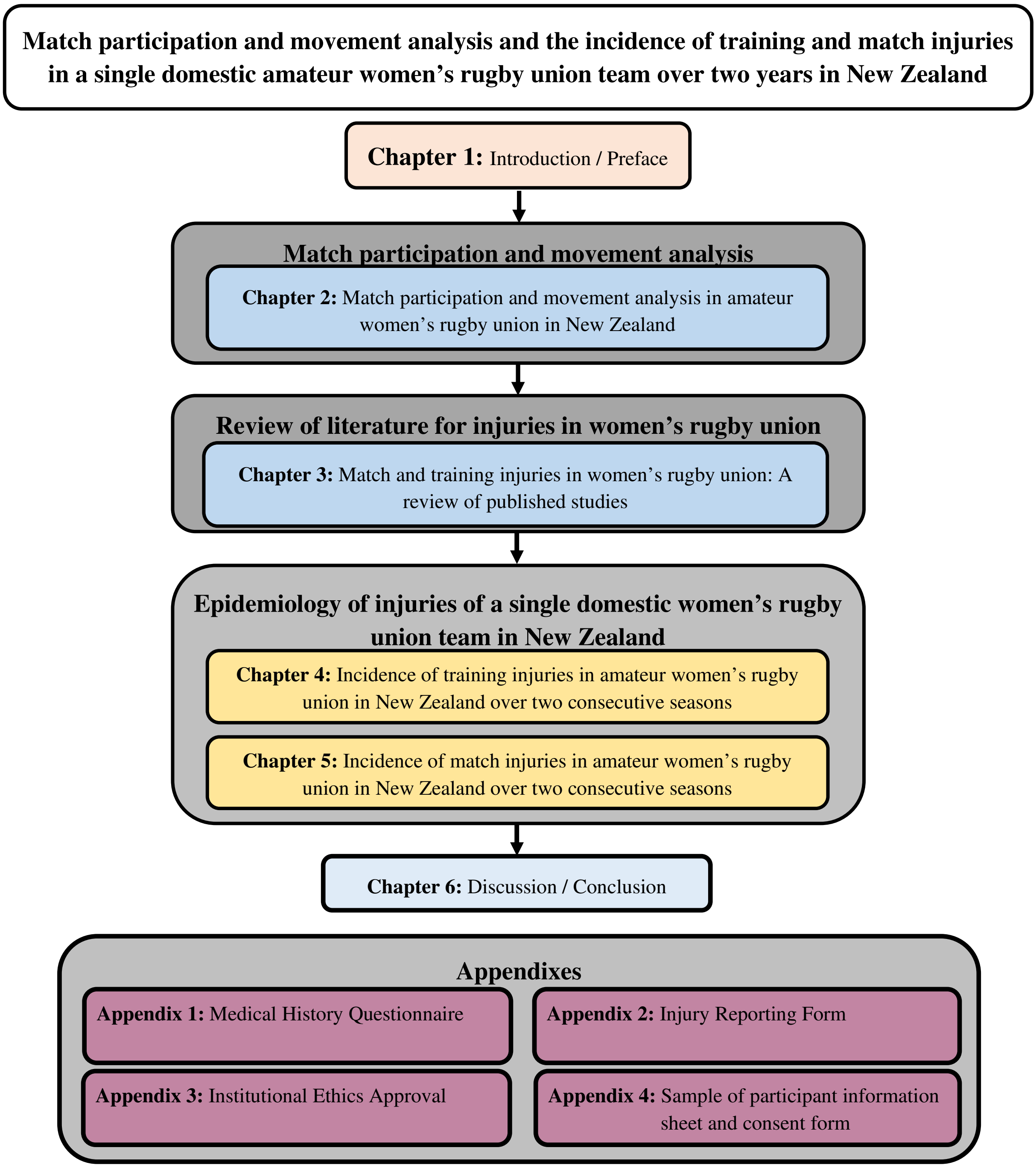

Figure 3: Overview of thesis chapter flow

Chapter 2 examined the **Match demands of participation in women's rugby union in New Zealand**. Chapter 2 (Submitted to *New Zealand Journal of Sports Medicine*) reports on the physical demands of amateur women's rugby union in New Zealand over two seasons and this was undertaken utilising heart rate monitoring and movement analysis.

This chapter was undertaken as there were no studies reporting on the movement analysis and physiological responses of amateur domestic club level women rugby union players nor any undertaken in New Zealand at the time of the study commencing. The publication resulting from Chapter 2 was:

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Match participation and movement demands in amateur domestic women's rugby union in New Zealand.

Having conducted the movement analysis, the research sought to focus on the same cohort for training and match injury epidemiology. At the time, there were no specific women's rugby union training injury studies published and, in addition, there were no women's rugby union match injury studies published for the amateur domestic club level New Zealand.

Chapter 3 of the thesis is focused on the **Review of the literature in women's rugby union**. Chapter 3 (published in *Sports Medicine,* 2019) comprises a review of the literature on women's rugby union match and training injuries by updating the descriptive data on the incidence, most commonly recorded cause, site, and type of injuries that occur in women's rugby-15s and rugby-7s match and training activities. The publication resulting from Chapter 3 was:

King, D., Hume, P.A., Cummins, C., Pearce, A.J., Clark, T.N., Foskett, A. & Barnes, M.J. Match and training injuries in women's rugby union: A systematic review of published studies. *Sports Medicine,* **49**(10): 1559-1574

Chapters 4 and 5 examined the **Epidemiology of injuries in women's rugby union match and training activities in New Zealand**. Chapter 4 (published in the *Journal of Science and Medicine in Sport*, 2020) reports on the incidence of training injuries in amateur women's rugby union in New Zealand over two consecutive seasons. Chapter 5 (published in *Advances in Orthopaedics and Sports Medicine,* 2020) reports on the incidence of match injuries in amateur women's rugby union in New Zealand over two consecutive seasons. Publications resulting from Chapters 4 and 5 were:

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Training injury incidence in an amateur women's rugby team in New Zealand over two consecutive seasons. *Journal of Science and Medicine in Sport*, 2020. **24**(6): 544-548

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Incidence of match injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons. *Advances in Orthopaedics and Sports Medicine,* 2020. **2**(129): 12 pages

Chapter 6 consists of a summary of the findings from the presented research projects, comments on limitations of the research studies, provides suggestions for future research, and provides concluding statements on the key findings from the thesis.

The appendices contain copies of the Medical History Questionnaire (Appendix I); Injury reporting form (Appendix II); Institutional ethics approval for Chapters 2, 4 and 5 (Appendix III); and Sample of a participant information pack and consent form (Appendix IV)

Participants enrolled in the research.

Although the thesis contains three distinct studies, they have used the same player cohort for all three studies, over the same reporting period. Over the duration of these studies, women's rugby union in this district commenced as a single level team competition whereby all teams played each other once in the first round. Following this, the teams were divided into a top four competition with the remaining teams playing in a lower level competition. This may have been three or five teams depending upon how many teams were entered. As a result, the players involved in the team had a vast range of experience, from no previous rugby exposure to 20 plus years of playing rugby union. Similarly, ages varied greatly and ranged from 18 yrs. old to 50 yrs. old. Having never played rugby union before, some players in the cohort had travelled from overseas to specifically experience women's rugby union in New Zealand.

Women's rugby union teams in this district were not afforded the support and supplies that the male premier players received, although they were theoretically playing at the same level (top amateur domestic competition rugby union). Throughout the duration of the study, there were no formal team medics available and often the responsibility fell to the researcher (a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment, and management) and although some teams were welcoming of the medical support, some were not and refused to have their players medically assessed on the sideline. As a result, the match injury findings may be higher in severity than reported in Chapter 5, as often the players were left to fend for themselves.

Injury Incidence Calculations Utilised.

Injury Incidence Rate.

The injury incidence rates for all match variables were calculated according to the following calculation (see Eq.1):[147, 149, 182]

$$IIR = \sum\left(\left(\frac{n}{nm * np * md}\right) * 1{,}000\right) \qquad \text{Eq. 1}$$

Where *n* = number of injuries recorded, *nm* = number of matches participated, *np* = number of players (15) and *md* = match duration (80 mins/60 mins = 1.33 hrs). These were expressed as the number of injuries sustained per 1000 match hours.

For example:

$$IIR = \sum\left(\left(\frac{138}{28 * 15 * 1.33}\right) * 1{,}000\right) = 247.0$$

Expected injury Incidence Rate.

To account for the different exposures each season exposure/risk hours were calculated. Expected injuries were then the same proportion of the total injuries as that competition season's exposure hours were of the total hours recorded (see Eq. 2):[147, 148, 150]

$$EIIR = \sum\left(\left(\frac{hr}{thr}\right) * tn\right) \qquad \text{Eq. 2}$$

Where *hr* = exposure hours for the period; *thr* = total exposure hours; and *tn* = total number of injuries recorded for the exposure hours.

For example:

$$EIIR = \sum\left(\left(\frac{239.4}{558.6}\right) * 138\right) = 59.1$$


Ford

Chapter 2: Match participation and movement analysis in amateur domestic women's rugby union in New Zealand.

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

Reference

King, DA., Hume, PA., Clark, TN., Foskett, A & Barnes, MJ. Match participation and movement analysis in amateur domestic women's rugby union in New Zealand.

Overview

Objective: To describe the movement analysis and heart rate data of amateur domestic women's rugby union match activities.

Design: Prospective cohort study.

Methods: Data were collected from 69 amateur female rugby union players over two consecutive seasons, using heart rate and microtechnology devices. Total distance, maximum velocity, Player Load ([PL] accumulated accelerometer-derived load), and individual PL vectors (PL forward [PL_F], PL sideward [PL_S] and PL vertical (PL_V]) and speed zones were examined. Analysis by player position, player group, matches won and lost, and years of competition were conducted.

Results: Inside Backs recorded a significantly higher mean distance (3920.4 ±1,437.3 m) per-match than Front-Row-Forwards ($\chi^2_{(1)}$=12.6; p=0.0004; z=-4.1; p<0.0001; d=0.55) and Outside-Backs ($\chi^2_{(1)}$=27.3; p<0.0001; z=-5.3; p<0.0001; d=0.xx). As a result, Backs recorded a significantly higher mean distance per-match (3,692.3 ±1,440.5 m) than Forwards ($\chi^2_{(1)}$=4.9; p=0.0273; z=-2.5; p=0.0132; d=0.36).

Conclusions: The results of this study suggest that the physical and physiological profile of the playing group at the amateur, domestic level of women's rugby union were similar and may be suggestive of generalised, rather than specialised, training regimes that fail to prepare players for higher levels of competition. Amateur women's rugby union may benefit from the incorporation of positional specific training that would provide forward playing positions with the opportunity to develop collision and contact abilities, while concurrently allowing Backs a greater opportunity to train their high intensity running capacity.

Introduction

Rugby union is an intermittent contact invasion game, involving periods of high-intensity activity (i.e. running, collisions, scrummaging) interspersed with lower-intensity activities including periods of rest.[180] The incorporation of microtechnology (Global Positioning System [GPS] and integrated tri-axial accelerometer) devices has enabled researchers and practitioners to quantify the workloads experienced within team sports such as rugby union.[66, 180] Furthermore, the use of microtechnology has been reported to be a reliable indicator of the physical demands of team sports.[66] Such technology provides a valid, reliable, and practical method of quantifying the players' external loads they experience during high-intensity exercise such as training and match activities.[269, 312, 321] The knowledge attained from the incorporation of GPS microtechnology enables specialist coaching staff to monitor detailed sport-specific data and positional specific movement profiles.[66, 180] This is deemed to be invaluable[110] to coaching staff assisting with the facilitation of optimal player training programmes and therefore, match-play preparation.[45]

The physiological demands of male rugby union players have been reported at the international,[267] professional[45] and amateur[180] levels of participation. These studies have reported that the total mean distances vary per-match from 3,698 m[165] to 6,545 m[45] and that the majority of the game (83 to 86% of the total distance) is played at low intensity.[45, 165] Total match-play distance is however, dependent upon playing position, with back playing positions (e.g. halfback, stand-off, centres, wings and fullbacks) (7,227 m) covering more distance than forward playing positions (6,680 m).[67] Positional differences are also reported to exist in relation to the intensity of match-play, with back playing positions covering a greater relative distance than forward playing positions (71.9 versus 66.7 $m \cdot min^{-1}$, respectively).[67] Contradictory literature has, however, been published stating that Back-playing positions cover slightly less high-speed distance (323 m vs 369 m) compared with the Forward-playing positions.[45] In addition to playing position, athletic calibre and age have been reported to impact on the distance covered throughout match-play with elite senior,[45] male amateur,[180] and junior[140] rugby union Forwards covering 5,850 m, 4,260 m and 3,511 m, respectively.

Despite the ever increasing body of knowledge on male participation in rugby union, there is a paucity of published studies[326] reporting on the physical and physiological demands of women's 15-a-side rugby union.[25, 44, 288, 297, 314] The match demands of women's rugby union have utilised video data collection,[314] and GPS sampling rates at 5 Hz,[297] 10 Hz[25, 44, 288] and 18 Hz[326] to obtain the data for respective studies. These studies[25, 44, 288, 297, 314] have reported a mean total distance per-match from 4,982 m[25] to 6,100 m,[288] with Forwards covering a mean distance of 5,049 m[25] to 5,616 m[44] per-match, while Backs covered a mean distance of 4,908 m[25] to 6,471 m[297] per-match. Of note, the study by Virr et al.[314] had limited numbers, with only four premier division club level players analysed per-match using video analysis and heart-rate monitors. The study by Suárez-Arrones et al.[297] utilised a 5 Hz GPS device on eight players during a single women's national rugby union match which may not be reflective of the demands occurring within the women's game or across a competition season.[25] Three studies[25, 44, 326] utilised a GPS system at a greater sampling rate (10 – 18 Hz) in order to increase the validity and reliability of the data obtained.[286]

Although the movement demands of women's rugby union have started to be explained, these studies have been undertaken at either premier[25] or elite[44, 297] level of competitions. More recently, one study[44] reported the running demands of women's rugby union in New Zealand, covering seven matches of a provincial team, over one competition. Thus the available literature to date provides limited insight into the imposed physical and physiological demands at the amateur domestic level of women's rugby union and this has been identified as a current concern in female sport.[65, 87] Therefore, the aim of this study was to quantify the match participation movement demands and physiological responses of senior amateur rugby union players by player roles and player positional groups over two consecutive seasons of domestic competition matches within New Zealand.

Methods

A prospective cohort descriptive study was undertaken to record the movement demands and physiological responses of 69 (age: 26.5 ±7.4 years [range: 17.6 to 48.5 years]; Height: 1.67 m ±0.08m [range 1.50-1.80 m]; mass 87.1 kg ±18.9 [range 50-127 kgs] years playing experience 4.3 ±4.2 years [range 0-18 years]) amateur women 15-a-side rugby union players, in New Zealand, from the same team over two consecutive years participating in a domestic level competition. A total of 34 players participated in the first season and 35 players competed in the second season. A total of 22 players participated in both competition seasons. All players were considered amateur, as they received no remuneration for participating in rugby union activities and derived their main source of income from other employment activities. Players competed in a single level competition where all teams (the number varied each year) played each other once before the top five were identified for a second-round top five and bottom six competition format. There were a total of 28 matches played under the rules and regulations of the New Zealand Rugby Football Union, with matches comprising of two 40-minute halves, with a resulting match exposure of 558.6 match exposure hrs.

Players were categorised according to their (1) playing group and (2) positional group.[45] These two groups were: (1a) Forwards (loose-head prop, hooker, tight-head prop, left lock, right lock, blind-side flanker, open-side flanker, and number eight) and (1b) Backs (halfback, fly-half, left wing, inside centre, outside centre, right wing, and full back); and (2a) Front-Row Forwards (loose-head prop, tight-head prop; left lock, right lock); (2b) Back-Row Forwards (hooker; blind-side flanker, open-side flanker, number eight); (2c) In-Side Backs (halfback; fly-half, inside centre, outside centre) and (2d) Out-Side Backs (left wing, right wing, full back). The hooker was included in the Back Row Forward's due to their roving style of play.[74] This would most accurately reflect the positions with similar match demands and enable comparisons to be undertaken. Utilising GPS and HR monitors, the players were measured during competition matches over the 2018 and 2019 competition seasons. Prior to the competition commencing, all players provided written consent to participate in the research and all procedures were approved by the institutional ethics committee prior to data collection.

Equipment and procedures

Players heart rates (HR) were continuously monitored during match participation using a portable monitor (Team Heart Rate System, Polar, Kempele, Finland). Player movements were monitored using microtechnology devices (OptimEye S5 device; Catapult Innovations, Melbourne, Australia), worn in a custom designed pocket, within a vest supplied by the device manufacturer, between the shoulder blades. The devices produced a 10 Hz GPS sampling rate through the in-built GPS-chip. Additionally, the devices contained a tri-axial accelerometer, gyroscope, and magnetometer sampling at 100 Hz (firmware v.5.27). As such, the device could continuously monitor linear and rotational accelerations, direction, and orientation of the player during match-play. Post-match data were downloaded and trimmed (to include on-field match-play time only) using proprietary software (Openfield, Catapult Innovations, Melbourne, Australia). The use of GPS technology has been utilised for research in several sporting codes including soccer, rugby league, Australian football league[66] and rugby union[180, 267] and has been reported to be acceptable[270] and ecologically[125] valid when assessing contact-based team sports. The OptimEye S5 has been previously reported to have valid and reliable distance and speed measurements, with very high correlation (r=0.94) for distance covered and acceptable within- and between-device reliability for measuring acceleration forces.[6, 14]

Mean and peak HR for each match were calculated for each player. During each match, the following time and GPS-based variables were analysed: match time (min), total distance (m) and maximum velocity (Vel_{Max} in $m.s^{-1}$). Additionally, accumulated accelerometer-derived loads (arbitrary unit known as PlayerLoad (PL)) were calculated by the sum of accelerations in the mediolateral [x], anteroposterior [y] and vertical [z] directions to provide a measure of the total stress upon an athlete as a result of accelerations, decelerations, changes of direction and impacts.[14] The frequency, duration, and distance of locomotive activities were also obtained as have been previously reported in previous female sports.[180, 296, 297, 326]

Player Load (PL) is expressed as the square root of the sum of the squared instantaneous rate of change in each of the three vectors. The application of this variable as a marker of training load has been established against both internal[48] and external load[287] measures. PL has been shown to be reliable both between (1.02% Coefficient of Variation (CV)) and within devices (1.05% CV) for dynamic movements.[69] Further, within a team sport circuit, the reliability of PL was reported as having a CV of 4.9%. Additionally, PL demonstrates high inter-unit reliability within Australian Rules Football (1.94% CV).[69] There is a strong relationship between PL and total distance[24] and as such, the vertical vector of the PL equation can be removed, thereby providing a measure of acceleration in the medio-lateral and anterior-posterior planes only (Player Load Two-Dimensional (PL2D)).[164] Such 2D measures have recently been shown [229] to be more sensitive to collision load within contact based team sports, such as rugby league. To report only low-speed activities (<2 $m{\cdot}s^{-1}$) the PL_{SLOW} was recorded. The PL_{SLOW} is accumulated through accelerations that are recorded in the three vectors of movement and is a proxy measure for the frequency and magnitude of low-speed exertions in rugby union (e.g., rucking and scrummaging)[276] that GPS or video analysis are unable to provide. The PL_{SLOW} is related (r^2=0.62) to collisions that occur during rugby union match-play.[278] The PL and 2DPL were recorded as well as the PL in each of the individual axes i.e. PL forward (PL_F), PL sideward (PL_S) and PL vertical (PL_V). Each PL variable were normalised for all match times (minutes) and reported in arbitrary units ($au \cdot min^{-1}$).

Statistical Analyses

All data were downloaded onto a Microsoft Excel spreadsheet and analysed with SPSS (IBM SPSS Statistics for Windows, Version 26.0.0 Armonk, NY: IBM Corp). Data were checked for normality and homogeneity of variance using a Shapiro-Wilk's test of normality. If tolerances were not met, equivalent non-parametric tests were utilised. Physical demands (i.e., PL, PL2D, PL_F, PL_S, PL_V, PL_{Slow}, Vel_{Max}) among player positions, matches won and lost, and years of competition were compared using a 1-way analysis of variance (ANOVA) with a Tukey post-hoc test to determine the source of differences.

Non-parametric data (Match duration, Distance, Relative Distance, HR_{Max} and HR_{Mean}, speed zones) were analysed with a Friedman repeated measures ANOVA on ranks. If notable differences were observed, a Wilcoxon signed-rank post-hoc test was conducted with a Bonferroni correction applied. A *t*-test was utilised to assess differences in player age. Cohen's effect size (*d*) were utilised to calculate practically meaningful differences between playing positions and for different levels of participation. Effect sizes of <0.19, 0.20-0.60, 0.61-1.20 and >1.20 were considered trivial, small, moderate, and large, respectively.[155] The level of significance was set at $p \leq 0.05$, and all data are expressed as means and standard deviations.

Results

Players in the 2019 cohort were significantly older than the 2018 cohort (28.9 ±8.0 yr. vs. 24.2 ±6.0; $t_{(17)}$=-2.4; p=0.0289; d=0.66) (see Table 2). Players were involved in a total of 28 matches for an exposure of 558.6 match hrs. Although 2018 recorded a higher mean distance per-match (3,604.2 ±1,365.6 m), compared with 2019 (3,463.1 ±1,273.0 m; $\chi^2_{(1)}$=2.6; p=0.1088; z=-1.2; p=0.2355; d=0.11) this difference was not significant. There was a statistically significant difference that showed players recorded a higher Vel_{Max} in 2019 when compared with 2018 (5.78 ±1.02 vs. 5.77 ±1.27 m.s^{-1}; $F_{(139,84)}$2.04; p=0.002; d=0.01). Players recorded a significantly higher max HR in 2018, per-match (192.6 ±34.7 beats-per-minute) compared with 2019 (185.6 ±34.4 beats-per-minute; $\chi^2_{(1)}$=9.1; p=0.0025; z=-2.6; p=0.0087; d=0.20). Players recorded a significantly higher mean distance in the 1.2 to 2.5 m·s^{-1} velocity band in 2018 when compared with 2019 ($\chi^2_{(1)}$=4.0; p=0.0450; z=-2.4; p=0.0160; d=0.18).

Front Row Forwards were significantly older (29.4 ±9.0 yrs.) than Inside Backs (23.0 ±4.5 yrs. $t_{(19)}$=3.2; p=0.0049) (see Table 3). As a result, Forwards were significantly older than Backs (28.6 ±8.1 vs. 23.3 ±4.5 yrs.; $t_{(29)}$=3.9; p=0.0005). Inside Backs recorded a significantly higher mean distance (3920.4 ±1,437.3 m) per-match than Front Row Forwards (3,189.2 ±1,195.7 m; $\chi^2_{(1)}$=12.6; p=0.0004; z=-4.1; p<0.0001; d=0.55) and Outside Backs (3,410.5 ±1,399.5 m; $\chi^2_{(1)}$=27.3; p<0.0001; z=-5.3; p<0.0001; d=0.36). As a result, Backs recorded a significantly higher mean distance per-match (3,692.3 ±1,440.5 m) than Forwards (3,409.7 ±1,201.9 m; $\chi^2_{(1)}$=4.9; p=0.0273; z=-2.5; p=0.0132; d=0.36).

Table 2: Summary of movement analysis and heart rate data for domestic amateur women's rugby union players in New Zealand by participation year and combined seasons of competition matches reported in distances and arbitrary units by means with standard deviation.

	2018	2019	Total
Players (n=)	34	35	69
Age (yr.)	24.2 ±6.0[b]	28.9 ±8.0[a]	26.5 ±7.4
Games (n=)	12	16	28
Match exposure (hr.)	239.4	319.2	558.6
Match time per player (min)	56.1 ±25.8	57.8 ±24.2	56.8 ±25.2
Match demands			
Distance (m)	3,604.2 ±1,365.6	3,463.1 ±1,273.0	3,546.6 ±1,329.2
Distance ($m{\cdot}min^{-1}$)	91.5 ±73.5	76.5 ±52.9	85.4 ±66.3
PL ($au{\cdot}min^{-1}$)	3.8 ±1.3	3.9 ±1.4	3.9 ±1.4
PL2D ($au{\cdot}min^{-1}$)	2.9 ±1.1	2.8 ±1.0	2.9 ±1.1
PL_F ($au{\cdot}min^{-1}$)	1.8 ±0.7	1.7 ±0.6	1.8 ±0.7
PL_S ($au{\cdot}min^{-1}$)	1.9 ±0.7	1.9 ±0.7	1.9 ±0.7
PL_V ($au{\cdot}min^{-1}$)	3.0 ±1.1	2.9 ±1.1	2.9 ±1.1
PL_{Slow} ($au{\cdot}min^{-1}$)	2.7 ±0.8	2.6 ±0.8	2.6 ±0.8
Vel_{Max} ($m.s^{-1}$)	5.8 ±1.3[b]	5.8 ±1.0[a]	5.8 ±1.2
Max HR ($b{\cdot}min^{-1}$)	192.6 ±34.7[b]	185.6 ±34.4[a]	189.5 ±34.8
Mean HR ($b{\cdot}min^{-1}$)	149.2 ±22.4	147.5 ±26.7	148.5 ±24.4
Running profile			
Band 1: 0.0 to 1.5 ($m{\cdot}s^{-1}$)	2,004.3 ±635.1	1,924.6 ±595.5	1,971.8 ±620.0
Band 2: 1.5 to 2.5 ($m{\cdot}s^{-1}$)	711.5 ±320.9[b]	654.6 ±295.5[a]	688.3 ±311.8
Band 3: 2.5 to 3.5 ($m{\cdot}s^{-1}$)	557.1 ±310.7	516.6 ±268.2	540.6 ±294.5
Band 4: 3.5 to 6.0 ($m{\cdot}s^{-1}$)	323.0 ±273.8	347.6 ±305.3	333.0 ±287.0
Band 5: 6.0 to 7.0 ($m{\cdot}s^{-1}$)	17.2 ±32.5	17.4 ±32.9	17.3 ±32.7
Band 6: 7.0 to 8.0 ($m{\cdot}s^{-1}$)	1.5 ±6.9	2.1 ±6.8	1.8 ±6.9

SD = standard deviation; min = minutes; m = metres; $au{\cdot}min^{-1}$ = arbitrary units per minute; PL = PlayerLoad; PL2D = PlayerLoad 2-dimension (frontal & sagittal); PL_F = player load in frontal plane; PL_S = PlayerLoad in sagittal plane; PL_V = PlayerLoad in transverse plane; PL_{SLOW} = Player Load <2 $m{\cdot}s^{-1}$ (metres per second); Vel_{Max} ($m{\cdot}s^{-1}$) = Maximum Velocity (metres per second); HR = Heart rate; $b{\cdot}min^{-1}$ = beats-per-minute; Significantly different (p<0.05) than (a) = 2018; (b) = 2019.

Table 3: Summary of movement analysis and heart rate data for domestic amateur women's rugby union players in New Zealand for the 2018, 2019 and combined seasons of competition matches for player groups and player roles reported in distances and arbitrary units by means with standard deviation.

	Front-Row Forwards	Back-Row Forwards	Forwards	In-Side Backs	Out-Side Backs	Backs
Players (n=)	24	16	40	20	9	29
Age (yr.)	29.4 ±9.0[c]	27.5 ±6.5[c]	28.6 ±8.1[f]	23.0 ±4.5[ab]	24.0 ±5.7	23.3 ±4.8[e]
Games (n=)	28	28	28	28	28	28
Match exposure (hr.)	154.3	154.3	308.6	154.3	115.7	270.0
Match time per player (min)	57.9 ±24.3	57.3 ±25.0	57.6 ±24.6	55.5 ±25.8	56.3 ±25.8	55.9 ±25.8
Match Demands						
Distance (m)	3,189.2 ±1,195.7[bc]	3,669.2 ±1,161.1[a]	3,409.7 ±1,201.9[f]	3,920.4 ±1,437.3[ad]	3,410.5 ±1,399.5[c]	3,692.3 ±1,440.5[e]
Distance ($m \cdot min^{-1}$)	76.2 ±62.1[c]	88.4 ±66.2	81.8 ±64.1	93.4 ±68.3[a]	83.9 ±68.4	89.1 ±68.4
PL ($au \cdot min^{-1}$)	3.6 ±1.3[c]	4.1 ±1.3	3.8 ±1.3	4.2 ±1.5[a]	3.5 ±1.3	3.9 ±1.4
PL2D ($au \cdot min^{-1}$)	2.7 ±1.0	3.1 ±1.0[c]	2.9 ±1.0	3.1 ±1.1[b]	2.5 ±0.9	2.9 ±1.1
PL_F ($au \cdot min^{-1}$)	1.7 ±0.6[d]	1.9 ±0.7	1.8 ±0.7	1.9 ±0.7	1.6 ±0.6[a]	1.7 ±0.7
PL_S ($au \cdot min^{-1}$)	1.8 ±0.7	2.1 ±0.6[c]	1.9 ±0.7	2.1 ±0.8[b]	1.7 ±0.6	1.9 ±0.7
PL_V ($au \cdot min^{-1}$)	2.7 ±0.9	3.1 ±1.0[c]	2.9 ±1.0	3.2 ±1.2[b]	2.7 ±1.0	3.0 ±1.2
PL_{Slow} ($au \cdot min^{-1}$)	2.7 ±0.9[d]	2.8 ±0.7[cd]	2.7 ±0.8	2.7 ±0.8[b]	2.3 ±0.7[ab]	2.5 ±0.7
Vel_{Max} ($m.s^{-1}$)	5.2 ±0.9	5.5 ±0.8	5.3 ±0.8	6.2 ±1.0	6.3 ±1.6	6.2 ±1.3
Max HR ($b \cdot min^{-1}$)	191.1 ±38.1	190.1 ±29.5	190.6 ±34.3	188.5 ±39.1	188.3 ±29.8	188.4 ±35.3
Mean HR ($b \cdot min^{-1}$)	148.9 ±27.1	151.1 ±22.7	149.9 ±25.1	145.5 ±26.6	148.7 ±18.7	146.9 ±23.5
Running Profile						
Band 1: 0.0 to 1.5 ($m \cdot s^{-1}$)	1,867.4 ±621.4[c]	2,042.2 ±518.5	1,947.7 ±582.0	2,095.9 ±635.9[ad]	1,875.8 ±667.3[c]	1,997.4 ±658.1
Band 2: 1.5 to 2.5 ($m \cdot s^{-1}$)	678.4 ±314.8[b]	741.2 ±300.3[a]	707.3 ±309.3	718.7 ±311.5[d]	605.7 ±306.5[c]	668.1 ±313.7
Band 3: 2.5 to 3.5 ($m \cdot s^{-1}$)	470.1 ±259.1[b]	602.6 ±294.7[ac]	530.9 ±309.3	610.4 ±319.9[bd]	477.4 ±272.2[c]	550.9 ±306.2
Band 4: 3.5 to 6.0 ($m \cdot s^{-1}$)	189.2 ±166.9[bcd]	277.8 ±212.2[acd]	229.9 ±193.8[f]	466.2 ±357.7[abd]	413.6 ±283.4[abc]	442.7 ±327.0[e]
Band 5: 6.0 to 7.0 ($m \cdot s^{-1}$)	6.0 ±17.7[cd]	5.0 ±14.6[cd]	5.5 ±16.3[f]	26.6 ±38.9[ab]	33.7 ±41.7[ab]	29.8 ±40.3[e]
Band 6: 7.0 to 8.0 ($m \cdot s^{-1}$)	0.8 ±3.9[cd]	0.1 ±1.2[cd]	0.5 ±0.3[f]	2.3 ±7.7[ab]	4.2 ±10.8[ab]	3.1 ±9.2[e]

SD = standard deviation; min = minutes; m = metres; $au \cdot min^{-1}$ = arbitrary units per minute; PL = PlayerLoad; PL2D = PlayerLoad 2-dimension (frontal & sagittal); PL_F = player load in frontal plane; PL_S = PlayerLoad in sagittal plane; PL_V = PlayerLoad in transverse plane; PL_{SLOW} = Player Load <2 $m \cdot s^{-1}$ (metres per second); Vel_{Max} (ms) = Maximum Velocity (metres per second); HR = Heart rate; $b \cdot min^{-1}$ = beats per minute; Significantly different (p<0.05) than (a) = Front-Row Forwards; (b) = Back-Row Forwards; (c) = Inside Backs; (d) = Outside Backs; (e) = Forwards; (f) = Backs; (g) = matches won; (h) = matches lost.

The Outside Backs recorded a significantly lower mean PL_{Slow} (2.3 ±0.7 au.min^{-1}) compared to Front Row Forwards ($F_{(112,6)}$=5.2; p=0.0211; d=0.50) and Back Row Forwards (2.7 ±0.9 au.min^{-}1; $F_{(112,6)}$=8.2; p=0.0064; d=0.71) (see Table 6). The Inside Back's recorded a significantly mean higher distance in the 0.0 to 1.5 m·s^{-1} (2,095.9 ±635.9 m·s^{-1}) than Front Row Forwards (1,867.4 ±621.4 m·s^{-1}; $\chi^2_{(1)}$=5.7; p=0.0168; z=-2.8; p=0.0047; d=0.36) and Outside Backs (1,875.8 ±667.3 m·s^{-1}; $\chi^2_{(1)}$=19.5; p<0.0001; z=-4.7; p<0.0001; d=0.34). Forwards recorded a significantly lower mean distance per-match in the 3.5 to 6.0 m·s^{-1} (229.9 ±193.8 m·s^{-1}) velocity band than Backs (442.7 ±327.0 m·s^{-1}; $\chi^2_{(1)}$=36.1; p<0.0001; z=-7.9; p<0.0001; d=0.72).

Discussion

This prospective study undertook to document the physical demands occurring in an amateur women's rugby union team during match participation over two consecutive seasons. The results identified the physical and physiological profile of individual positional groups in amateur women's rugby union throughout match participation. Given the paucity of the availability of both GPS- and accelerometer-based variables in amateur women's rugby union, this study highlighted the importance of integrating microtechnology into the routine monitoring of amateur women's sports such as rugby union.

The reporting of total distance covered per-match in the current study revealed differences between the playing groups, but provides little comparison with other sporting studies.[66] However, by reporting the mean relative distance (m·min^{-1}) per-match, this reflects the intensity of the workload the player's undertake during the activity.[66] For example, by comparing the total distances in women's football (3,977 m to 9,997 m; mean: 7,797 ±1,976 m), women's hockey (5,541 to 6,154 m; mean: 5,824.5 ±329.5 m)[151] and other studies in women's rugby union (4,982 to 5,820 m, mean: 5,576.5 ±398.5 m),[25, 44, 297] it can be seen that the mean distance per-match in the current study was much lower by 40% (rugby) to 55% (football) of the total distances recorded. However, this does not account for the match duration. When comparing the relative distances in women's football (79.3 to 118.0 $m \cdot min^{-1}$: mean 101.0 ±11.9 $m \cdot min^{-1}$), hockey (79.0 to 115.0 $m \cdot min^{-1}$: mean: 98.5 ±15.6 $m \cdot min^{-1}$)[151] and rugby (54.8 to 68.0 $m \cdot min^{-1}$; mean: 61.4 ±9.3 $m \cdot min^{-1}$),[25, 44, 297] the relative distance per-match in the current study was less (38.3 ±13.7 $m \cdot min^{-1}$) by 38% (rugby) to 62% (football) of the relative distances covered per match. The differences between the current cohort and other studies indicated that the total and relative distances covered at the amateur club level were much lower and may be attributed to a difference in player fitness, playing style, match intensity, and player preparedness at the higher levels of participation.[165]

Throughout the matches, the Back-playing positions travelled greater total distances, including distances above 6.0 $m \cdot s^{-1}$ and accumulated PL and PL_V values, compared with the Forward-playing positions. This finding was not surprising, given the vertical component of running as this accelerometer-based metric accounts for between 50% to 60% of the overall three-dimensional load.[14] Interestingly, Back-playing positions accumulated a similar mean PL2D throughout match-play. This finding was highlighted in a previous study where players with a similar PL2D were likely to undertake comparable collisions and tackles.[64] A possible suggestion for this finding is that Backs have both short bursts of changes in direction and are more often being tackled in open space. Conversely, the PL and PL_V for Forwards is comprised predominantly of collision and tackle events in confined spaces, such as rucks and mauls, at a lower velocity. Although there were some subtle differences for a number of metrics (PL, PL_V and PL2D), the variance between positions was somewhat trivial from a practical perspective, suggesting that minimal differences were apparent in the physical demands of match-play at this level of competition. Further, such findings highlight the importance of incorporating a variety of external load metrics into the routine monitoring of collision-based sports such as women's rugby union, in order to adequately quantify the workload across different playing positions.

Although differences were noted between positional groups in regard to PL_{Slow}, from a practical perspective it appears that both Forward and Back-playing positions accumulate similar loads from low velocity activities, such as physical collisions and tackles. This was contrary to previous work reporting that Forwards attained greater PL_{Slow} than their Back playing counterparts.[271] Such discrepancies may, however, be attributed to altered physical capacities and game play strategies between the examined cohorts.

The use of heart rate monitors have been previously utilised as an indicator for determining the physiological demands of the players[60] and can be a useful index of the overall physiological strain and quantification of the total work performed during match activities.[60] Although heart rate may be an effective way to measure the intensity of activities,[120] other factors may also influence the heart rate of players, such as the level of fatigue the player is experiencing. The maximum heart rates reported in this study may be an indication of the fatigue the players experienced during match participation and further studies may consider a fatigue monitoring scale to be incorporated into the study parameters.

The results of this study suggested that the physical and physiological profile of the playing group at the amateur domestic level of women's rugby union were quite similar and may be suggestive of generalised, rather than specialised, training regimes that fail to prepare players for higher levels of competition. Amateur women's rugby union may benefit from the incorporation of positional specific training that would provide Forward-playing positions with the opportunity to develop collision and contact abilities, while concurrently allowing Backs a greater opportunity to train their high intensity running capacity. Although the use of microtechnology, such as GPS, may not be available to the majority of amateur women's rugby union teams, measurements such as heart rate and the use of scales such as the Borg Rating of Perceived Exertion (RPE)[50] should be considered. The various RPE scales have been reported[4, 39, 204] to be a valid measure of exercise intensity independent of participant sex[39, 90, 126] and age.[258, 277] These scales may provide the coaching and management team with an alternative means of assessing and monitoring exercise intensity[55, 236] in women's rugby union.

Limitations

The current study followed a domestic women's rugby union team during two years of competition matches. Therefore, the results reported in this study should be interpreted with caution and may not be transferable to other levels of rugby union participation. The assumptions, calculations and thresholds utilised within this study are based upon the thresholds previously reported[67, 297] for male rugby union participants. It is possible that these zones are not applicable to women's rugby union and, therefore, amending the speed thresholds to account for the physical capabilities of women should be considered in future research.[11, 27] Additional information such as the number of tackles, contact events and scrums were not obtained and future studies would benefit from the inclusion of this information to assist with PL assessment.

Conclusions

The game participation physical demands in an amateur domestic women's rugby union team in New Zealand measured using heart rate and movement analysis, indicated there was very little difference between positional groups. It was also apparent that the physiological profiles gathered from using microtechnology were much lower in rugby union when compared with other women's sports. Given the limited availability of microtechnology data at this level of competition, the study highlights the importance of integrating a variety of external load metrics into the routine monitoring of collision-based sports such as rugby union.

Practical Applications

- The findings of this study can be utilised to assist with the training and preparation for specific tactical strategies that are used in match environments for women's rugby union.
- Training should focus on the development of aerobic capacity for both attack and defending roles as well as skill development and the development of anaerobic capacities.

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Douglas Alsitair King
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Chapter 3: Match and Training Injuries in Women's Rugby Union: A Review of Published Studies

This chapter comprises the following paper published in *Sports Medicine*:

Reference

King, DA., Hume, PA., Cummins, C., Pearce, AJ., Clark, TN., Foskett, A. & Barnes, M. Match and Training injuries in women's rugby union: A systematic review of published studies. *Sports Medicine.* 2019. **40**(2): 163-178.

Overview

Background There is a paucity of studies reporting on injuries in women's rugby union.

Objective The aim of this systematic review was to describe the injury epidemiology for women's rugby-15s and rugby-7s match and training environments.

Methods Systematic searches of PubMed, SPORTDiscus, Web of Science Core Collection, Scopus, CINAHL(EBSCO) and ScienceDirect databases using keywords.

Results Ten articles addressing the incidence of injury in women's rugby union players were retrieved and included. The pooled incidence of injuries in women's rugby-15s was 19.6 (95% CI: 17.7-21.7) per1,000 match-hours (hr). Injuries in women's rugby-15s varied from 3.6 (95% CI: 2.5-5.3) per 1,000 playing-hr (including training and games) to 37.5 (95% CI: 26.5-48.5) per 1,000 match-hr. Women's rugby-7s had a pooled injury incidence of 62.5 (95% CI: 54.7-70.4) per 1,000 player-hr and the injury incidence varied from 46.3 (95% CI: 38.7-55.4) per 1,000 match-hr to 95.4 (95% CI: 79.9-113.9) per 1,000 match-hr. The tackle was the most commonly reported injury cause with the ball carrier recording more injuries at the collegiate (5.5 [95% CI: 4.5 to 6.8] vs. 3.5 [95% CI: 2.7 to 4.6] per 1,000 player-game-hr; $\chi^2_{(1)}$=6.7; p=0.0095), and Rugby World Cup for women (RWC(W)) (2006: 14.5 [95% CI: 8.9 to 23.7] vs. 10.9 [95% CI: 6.2 to 19.2] per 1,000

match-hr; $\chi^2_{(1)}$=0.6; p=0.4497; 2010: 11.8 [95% CI: 6.9 to 20.4] vs. 1.8 [95% CI: 0.5 to 7.3] per 1,000 match-hr; $\chi^2_{(1)}$=8.1; p=0.0045) levels of participation. Concussions and sprains/strains were the most commonly reported injuries at the collegiate level of participation.

Discussion Women's rugby-7s had a higher un-pooled injury incidence than women's rugby-15s players based on rugby specific surveys and hospitalisation data. The incidence of injury in women's rugby-15s and rugby-7s was lower than men's professional rugby-15s and rugby-7s competitions but similar to male youth rugby-15s players. Differences in reporting methodologies limited comparison of results.

Conclusion Women's rugby-7s resulted in a higher injury incidence than women's rugby-15s. The head/face was the most commonly reported injury site. The tackle was the most common cause of injury in both rugby-7s and rugby-15s at all levels. Future studies are warranted on injuries in women's rugby-15s and rugby-7s.

PROSPERO registration number: CRD42018109054 (last updated on 17th January 2019).

Introduction

Rugby union is an international collision sport played at junior,[19, 23, 167, 281] amateur,[19, 46, 59, 79, 127, 208, 261, 331] elite[15, 230] and professional[17, 31-33, 121, 152, 301] levels of participation. The game of rugby union has gained international popularity with approximately 8.5 million registered players in over 121 countries worldwide.[332] The rugby-15s game is typically played over two 30–40 min halves interspersed by a 10-min rest interval, depending upon the participation level, with typical rest periods between competitive matches of four to seven days.[80, 89, 243] More recently the popularity of the shortened version of rugby union, termed rugby-7s, where seven players compete on a full side rugby pitch over two 7-min halves, has increased.[101] Rugby-7s matches are typically held during tournaments via a multi-team or multigame structure over a shortened period (typically two to three days).[101]

Traditionally seen as an amateur sport for women, participation has necessitated that women partake in rugby-15s and rugby-7s activities while still maintaining their normal work/family life.[68] Over the past few decades, the participation of women in rugby-15s and rugby-7s has grown[51] in countries such as Canada, Australia, New Zealand, Great Britain, South Africa and the United States of America and in the Olympics.[101, 143]

In both formats of the game (rugby-15s and rugby-7s), players are often exposed to repeat high-intensity activities (e.g. running, tackling, rucks, mauls, passing and sprinting) interspersed with short bouts of low intensity activity (e.g. jogging and walking).[23, 58, 80, 127] Exposure to increasing 'ball-in-play' times, repetitive physical collisions and tackles is common in both rugby-15s and rugby-7s, placing adverse stresses on the body.[15, 23, 33, 58, 80, 127] As a consequence of this participation there is an increased risk of musculoskeletal injuries occurring.[23, 58, 80, 127] In addition to this, there are biomechanical factors that differ between the sexes, with females reportedly having lower physiological aspects (e.g. reduced speed and less agility, lower muscular power, lower estimated maximal aerobic power) when compared with males, placing them at a higher injury risk.[196]

In a review of trends in both rugby-15s and rugby-7s,[36] the incidence of match injuries varied from 3.6 (women) to 218.0 (men's professional) per 1,000 player-hr depending upon the injury definition utilised. More recently,[322] it has been reported that professional male rugby has an incidence of 81 per 1,000 player match-hr and an incidence of 3.0 per 1,000 player-training-hr. Despite the increasing number of studies reporting on men's rugby-15s and rugby-7s injuries, there is a paucity of studies reporting on women's rugby-15s and rugby-7s injuries.[36] In order to minimize the injuries that occur in women's rugby-15s and rugby-7s, a full understanding of the incidence and etiology of the injuries[91] that occur is required.

The aim of this systematic review was to describe the injury epidemiology of women's rugby-15s and rugby-7s at all levels of participation in both match and training environments. In addition, where comparable methodologies were available, overall estimates of the injury incidence were calculated by pooling the data to collate and summarise the injury data to date, and identify/highlight risk factors for injury[322] of women rugby-15s and rugby-7s participants.

Methods

This review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) on 14th October 2018 (Registration No: CRD42018109054). Guidelines for the reporting of systematic reviews (PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses[235, 320]) and observational studies (STROBE: STrengthening the Reporting of OBservational studies in Epidemiology[315]) were followed. The PRISMA and STROBE guidelines contain checklists that were utilised for the conducting and reviewing of the included studies.

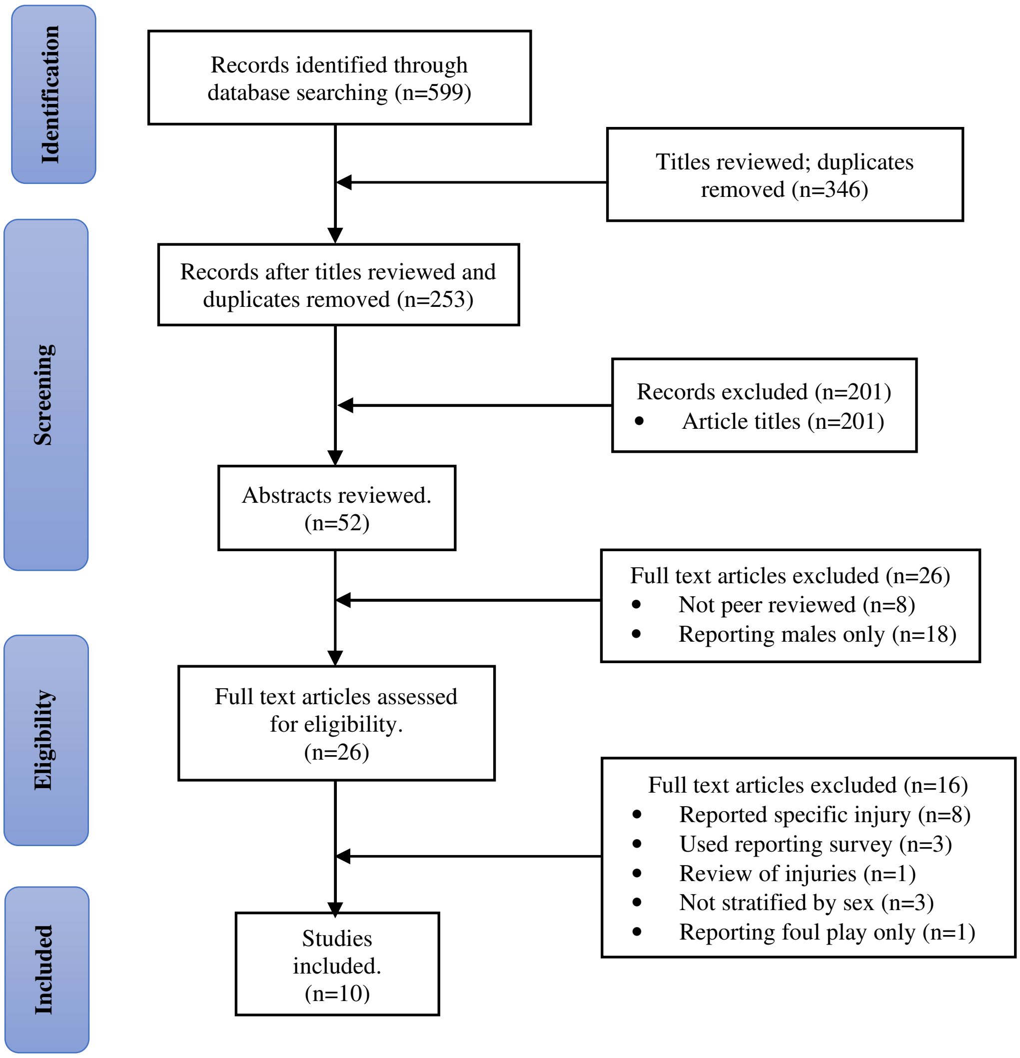

Figure 4: Flow of identification, screening, eligibility, and inclusion for the literature review on women's rugby union injuries.

Search strategy for identification of publications

A total of 599 studies published from January 1990 to August 2018 were identified through a search of PubMed (n=12), SPORTDiscus (n=32), Web of Science Core Collection (n=34), Scopus (n=128), CINAHL (EBSCO) (n=9), and ScienceDirect (n=384) databases (see Figure. 4). The keywords utilised for the search of relevant research studies included combinations of 'Rugby Union', 'Women*', 'Female', and 'Inj*'.

To establish some control over the heterogeneity of the different studies,[295] inclusion criteria were established. Papers were included if they met the following inclusion criteria in the study: available in English; published in a peer reviewed journal or book; reporting on women's rugby-15s and rugby-7s; a prospective cohort study; provided a clear definition of a reportable injury; were full-text versions; and reported on one or more epidemiological data aspects (i.e. match or training injury incidence rates; incidence of new or recurrent injuries; incidence of injuries in Forwards and Backs; period of match incidence; type of injuries; site of injuries; severity of injuries; injury incident).

All references were downloaded into a dedicated EndNote library (Endnote, X8). The library was reviewed, and duplicate records were identified and removed. The title and abstracts of the remaining studies were assessed for relevance, and non-relevant studies were discarded. The full-text versions of the remaining articles were then retrieved and evaluated against the inclusion criteria. Those studies meeting the inclusion criteria were included in the review. The bibliographies of the included studies found in the literature search were reviewed to identify any additional studies.

Assessment of publication quality

The included studies were independently assessed by two authors (DK, AJP) reporting on the article quality utilizing the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement (see Table 3).[315] The statement provides a 22-item checklist guidance on the reporting of observational studies in order to facilitate a critical appraisal of the study and for the interpretation of the results. Following the appraisal, the included studies were categorised as poor, moderate or good quality based on the percentage of fulfilled items on the STROBE checklist, with cut-off values of < 50, 50-80 and > 80% respectively.[251]

Data extraction

Those studies meeting the inclusion criteria underwent data extraction for information pertaining to level of participation, number of participants, injury definition utilised, injury site and type, and player position/group. Some studies[101, 217] reported on women's rugby-7s while others[19, 46, 57, 79, 175, 257, 285, 302] reported on women's rugby-15s. Both the rugby-15s and rugby-7s studies were included in the review but were evaluated separately. Not all studies reported the same information in relationship to injury site, injury type and injury severity. Grouping of the data by injury region, i.e., head/neck, was undertaken to enable pooling of the data provided by the included studies. Although not every study included in the review reported on each injury type, all the studies did report on concussion. However, no definition was provided for the identification of concussion in any study.

Pooled analysis of injury incidence

A pooled analysis of women's rugby-15s and rugby-7s was undertaken on those studies where homogeneity occurred in terms of the injury definition utilised and the reporting of injury incidence was per 1,000 match or training-hr. This strategy has been previously utilised in rugby-15s[94, 322] and rugby league[136, 184, 192] epidemiological studies to combine the information provided into a single estimate.[22, 225] By pooling the data, the information provided can then be statistically re-analysed providing more precise injury data.[22]

Statistical analysis

Data from the individual studies were combined as previously described.[136] Incidence rates and 95% confidence intervals (CIs) were calculated where data were available and reported according to the methodology utilised in the individual studies. Reviewer inter-rater reliability was assessed utilising the Cohen's Kappa (κ) statistic. The level of agreement was categorized as none, minimal, weak, moderate, strong and almost perfect with cut-offs of < 0.20, 0.21-0.39, 0.40-0.59, 0.60-0.79, 0.80-0.90, and > 0.90 respectively.[227] To test for significant differences between studies and player positions, chi-squared (χ^2) goodness-of-fit tests were utilised where the data were available.

Table 4: Level of participation, injury rate reported, injury definitions utilised and reporting quality of included studies reporting on injuries in women's rugby-15s and rugby-7s.

Reference and Quality rating	Level of participation	Injury rate	Injury definition used
Bird et al.[19] Moderate	Community / school	6.4 per 100 player games. 0.7 per 100 player practices	An injury that required medical treatment or that caused the player to miss at least one scheduled game or team practice.
Carson et al.[46] Moderate	National & regional (Canadian)	20.5 per 1,000 player hours; 1.2 per 1,000 practice hours	A rugby related event that kept a player out of practice or competition > 24 hours or required the attention of a physician (e.g., suturing lacerations) and in addition included all dental, eye and nerve injuries and concussions
Doyle et al.[79] Moderate	International	3.6 per 1,000 playing (match and training) hours	Any event which prevented the player from partaking in normal physical activity (training or playing in a match) for greater than 24 h and/or required the attention of a doctor (including dental, nerve, eye, laceration injuries and concussion)
Collins et al.[57] Moderate	High school	4.1 per 1,000 total rugby athletic exposures; 19.5 per 1,000 total match exposures; 1.0 per 1,000 total practice exposures	An injury that occurred as a result of participation in an organized high school rugby match or practice; required medical attention by a club physician, certified athletic trainer, personal physician, emergency department, or urgent care facility; and resulted in restriction of the high school rugby player's participation in regular school or rugby activities for 1 or more days beyond the day of the injury
Kerr et al.[175] Moderate	Collegiate	17.0 per 1,000 player game hours	An injury: (1) occurring as a result of participation in an organized intercollegiate game or practice; and (2) requiring medical attention by a team athletic trainer, physician, or other person during or after the game or practice, or (3) resulting in any restriction (self-restricted or restricted by a medical professional) of the athletes' participation for > 1 days beyond the day of injury, or resulting in a dental injury, regardless of time loss.
Schick et al.[285] Moderate	Rugby World Cup for women	37.5 per 1,000 player hours	Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury.
Taylor et al.[302] Moderate	Rugby World Cup for women	35.5 per 1,000 player hours; 3.0 per 1,000 training hours	Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury.
Peck et al.[257] Moderate	Collegiate (military)	29.1 per 10,000 athlete exposures	Any new event that occurred during a rugby practice or match that required medical attention from an athletic trainer, physician, or other medical provider
Ma et al.[217] Moderate	Rugby-7s	97.7 per 1,000 player hours (total injuries); 46.3 per 1,000 player hours (missed matched)	Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury.
Fuller et al.[101] Moderate	Rugby-7s Olympics 2016	95.4 per 1,000 player match hours	Any injury sustained during the period of rugby-7s tournament (match or training session) that prevented a player from taking a full part in all training activities and/or match play for more than one day following the day of injury

Results

Ten papers[19, 46, 57, 79, 101, 175, 217, 257, 285, 302] were included in the study, all of which were of moderate quality. Two of the included studies were undertaken either as a review of injury records[57] or through telephone contact[19] after the games had been completed. The other studies[46, 79, 101, 175, 217, 257, 285, 302] included in this review reported on injuries prospectively. The study length varied from one competition season[19, 46, 79, 175] or tournament[285, 302] through to five years[257] of data collection. One study[257] was included as it reported on female rugby-15s and rugby-7s injuries but combined both rugby-15s and rugby-7s in the data. This study was included in the systematic review but not in the pooled analysis due to the combining of data across both rugby-15s and rugby-7s. Player ages were reported by some but not all of the studies and ranged from 14 to 43 yr. old.[46, 79, 101, 217]

Injury definitions

The studies included in this review utilised various injury definitions (see Table 4) and this limited the inter-study comparisons on some,[19, 57, 79, 257] but not all,[46, 101, 175, 217, 285, 302] of the identified studies. Although all of these studies were based on a missed-match or time-loss injury definition, they were reported in a variety of different exposures, i.e. per 100 player games or practices,[19] per 1,000 total (match and training combined) rugby-hr or athletic exposures (AE),[46, 57] or per 1,000 game-hr,[79, 101, 217, 257, 285, 302] again limiting inter-study comparison.

Table 5: Summary of match and training exposures, number of injuries and injury incidence reported for studies reporting on injuries in women's rugby-15s and rugby-7s participation by participation level and pooled injury incidence.

Activity and Level of Participation	Exposure hr	No. Injuries	Incidence (95% CI)
Match injuries reported per 1,000 match/player-hrs.			
Women's rugby-15s			
World Cup			
Schick et al.[285]	1,200	45	37.5 (28.0-50.2)[abc]
Taylor et al.[302]	1,100	39	35.5 (25.9-48.5)[abc]
Pooled World Cup[285, 302]	2,300	84	36.5 (28.7-44.3)[abc]
National			
Carson et al.[46]	1,513	31	20.5 (13.3-27.7)[ac]
Collegiate			
Kerr et al.[175]	15,780	269	17.1 (15.0-19.1)[ab]
Rugby-15s pooled analysis[46, 175, 285, 302]	19,593	384	19.6 (17.6-21.6)[a]
Women's rugby-7s			
Amateur / Elite candidate			
Ma et al.[217]	2,590	120	46.3 (38.7-55.4)[d]
Elite			
Fuller et al.[101]	1,279	122	95.4 (79.9-113.9)[ef]
Rugby-7s pooled analysis[101, 217]	3,869	242	62.5 (54.7-70.4)
Training injuries reported per 1,000 training/practice hrs.			
World Cup			
Schick et al.[285]	4,681	14	3.0 (1.8-5.0)[g]
Taylor et al.[302]	5,375	1	0.2 (0.0-1.3)[g]
Pooled World Cup[285, 302]	10,056	15	1.5 (0.9-2.5)[g]
National			
Carson et al.[46]	2,445	4	1.2 (0.4-3.1)[g]
Rugby-15s training pooled analysis[46, 285, 302]	12,501	19	1.5 (0.8-2.2)[g]
Match injuries reported in another format			
Women's rugby-15s			
International			
Doyle et al.[79]	7,440 hr[h]	27	3.6 (2.5-5.3) per 1,000 player-game hr[i]
High school			
Collins et al.[57]	N/R	77*	19.5 per 1,000 match exposures
Community			
Bird et al.[19]	N/R	N/R	6.1 per 100 player games
Combination of rugby-15s and rugby-7s data			
Peck et al.[257]	68,633 AE	200*	29.1 (25.4-33.5) per 10,000 AE[i]
Training injuries reported in another format			
International			
Doyle et al.[79]	7,440 hr	9	1.2 (0.6-2.3) per 1,000 player-game hr[i]
Collegiate			
Collins et al.[57]	N/R	N/R	1.0 per 1,000 practice exposures
Kerr et al.[175]	23,746 AE	131	5.5 (4.7-6.5) per 1,000 AE
Community			
Bird et al.[19]	N/R	N/R	1.2 per 100 player practices

a = per 1,000 match-hours; b = Significant difference (p<0.05) vs. national level; c = Significant difference (p<0.05) vs. collegiate level; d = Significant difference (p<0.05) vs. amateur level; e = Significant difference (p<0.05) vs. amateur/elite level; f = Pooled match injury rate; g = per 1,000 training hours; h = Significant difference (p< 0.05) vs. World Cup; i = Training and match combined; hr = hours; AE = athlete exposures; N/R = not reported

Injury incidence

In women's rugby-15s, the injury rate varied from 3.6 (95% CI: 2.5 to 5.3) per 1,000 playing-hr (including rugby training and games)[79] to 37.5 (95% CI: 26.5 to 48.5) per 1,000 match-hr[285] for the Rugby World Cup for women (RWC(W)) competition (see Table 3). Different reporting methodologies were utilised across the studies included in this review limiting inter-study comparisons. Some,[175, 217, 285, 302] but not all,[19, 46, 57, 79, 257] of the included studies were published after the 2007 consensus statement on injury definition and data collection procedures.[98] For these studies, the incidence of women's rugby-15s injuries ranged from 17.1 (95% CI: 15.1 to 19.1)[175] to 37.5 (95% CI: 28.0 to 50.2)[285] per 1,000 match-hr. When pooled together, there were more match injuries recorded at the RWC(W) level of participation (36.5 [95% CI:28.7 to 44.3] per 1,000 match-hr)[285, 302] than at the national[46] ($\chi^2_{(1)}$=7.8; p=0.0053) and collegiate[175] ($\chi^2_{(1)}$=39.0; p<0.0001) levels of participation.

Only four studies[46, 57, 285, 302] reported on injuries that occurred in women's rugby-15s training. The incidence of training injuries varied from 1.0 per 1,000 practice exposures[57] to 3.0 (95% CI: 1.8 to 5.0) per 1,000 training-hr.[285] For those studies[46, 285, 302] that utilised the 2007 consensus statement, the incidence of rugby-15s training injuries was similar (1.2 [95% CI: 0.4 to 3.1][46] to 3.0 [95% CI: 1.8 to 5.0][285] per 1,000 training-hr). There were more rugby-15s training injuries at the 2006 RWC(W) (3.0 [95% CI: 1.8 to 5.0] vs. 0.2 [95% CI: 0.0 to 1.3] per 1,000 training-hr; $\chi^2_{(1)}$=13.2; p=0.0003) compared with the 2010 RWC(W).[285, 302]

For studies reporting on rugby-7s total injuries, the injury incidence varied from 46.3 (95% CI: 38.7 to 55.4)[217] to the pooled incidence of 95.4 (95% CI: 79.9 to 113.9)[101] per 1,000 match-hr ($\chi^2_{(1)}$=32.9; p<0.0001). Although Ma et al.[217] reported a rugby-7s missed match injury incidence of 46.3 per 1,000 match-hr when separated into elite (32.6 [95% CI: 16.1 to 49.1] per 1,000 match-hr) and non-elite (49.3 [95% CI: 39.9 to 58.7] per 1,000 match-hr), the incidence varied. Rugby-7s training injuries ranged from 0.95 (95% CI: 0.4 to 2.1) per 1,000 player training-hr for elite players to 2.2 (95% CI: 1.2 to 4.1) per 1,000 player training-hr for Olympic rugby-7s participants.[101]

Pooled injury incidence

The pooled incidence of injuries in women's rugby-15s match activities was 19.6 (95% CI: 17.7 to 21.7) per 1,000 match-hr[175, 285, 302] (see Table 5). In rugby-7s, the pooled injury incidence was 62.5 (95% CI: 54.7 to 70.4) per 1,000 player-hr.[101, 217] There were more pooled injuries recorded in women's rugby-7s (62.5 [95% CI: 54.7 to 70.4] per 1,000 match-hr) when compared with the pooled women's rugby-15s; (19.6 [95% CI: 17.6 to 21.6] per 1,000 match-hr; $\chi^2_{(1)}$=223.3; p<0.0001). For training injuries,[46, 285, 302] the pooled injury rate was notably lower at 1.5 (95% CI: 0.8 to 2.2) per 1,000 training-hr.

Level of participation

The level of participation included community,[19] high school,[57] collegiate,[175, 257] national,[46] international[79] and World Cup competitions.[285, 302] The two women's rugby-7s studies that were included in this review were at amateur under 19 yr. old (U19) / elite-national candidate[217] and elite-international[101] levels of participation including a competition at the Olympic Games.

Player position

In reporting on rugby-15s, some of the studies[19, 79, 175, 285, 302] included in the review provided information pertaining to player position. Only two studies reported on specific player positions with the prop (1.2 [95% CI: 0.6 to 2.3] per 1,000 playing-hr [match and training])[79] and the centre (2.9 [95% CI: 2.2 to 3.9] per 1,000 player-game-hr)[175] being the most commonly injured player. When grouped into player positional roles (Forwards and Backs), the results varied by the level of participation. It was reported that Backs recorded more injuries at the community (21.0 vs. 16.7 per 100 player matches)[19] and elite (30.7 [95% CI:19.3 to 48.7] vs. 40.9 [95% CI: 26.7 to 62.7] per 1,000 match-hr)[302] levels of participation when compared with Forwards. Other studies reported that Forwards recorded more injuries than Backs at the collegiate (9.1 [95% CI: 7.8 to 10.7] vs. 7.9 [95% CI: 6.6 to 9.4] per 1,000 total rugby athletic-hr)[175] and elite (41.1 [95% CI: 24.3 to 57.9] vs. 32.8 [95% CI: 18.8 to 46.8] per 1,000 match-hr [recalculated])[285] levels of participation.

When reporting on rugby-7s, Backs recorded more injuries (48.6 [95% CI: 38.1 to 61.2] vs. 38.7 [95% CI: 28.0 to 52.2] per 1,000 match-hr)[217] when compared with Forwards. When separated into elite and non-elite, there were more injuries recorded for non-elite players when compared with elite players in the Forwards (40.5 [95% CI: 28.5 to 55.8] vs. 30.4 [95% CI: 11.2 to 66.3] per 1,000 player-hr) and Backs (51.7 [95% CI: 39.8 to 66.2] vs. 34.2 [95% CI: 15.7 to 64.0] per 1,000 player-hr] over the duration of the study. There were no player position injury rates reported for the elite tournament and Olympic rugby-7s competitions.[101] No study reported on player positions in training activities.

Injury site

Reporting on community women's rugby-15s activities, Bird et al.[19] did not separate out the injury site or type into the male and female cohort, and, therefore, these data could not be extracted for analysis. For those studies reporting injury sites, these varied by participation level. At the collegiate level of participation, the head/face was the most common injury site (3.5 [95% CI: 2.7 to 4.5] per 1,000 player-game-hr).[175] At the international level of participation, the knee was the most common injury site (0.8 [95% CI: 0.4 to 1.8] per 1,000 player-hr [match and training]).[79] At the high school level of participation, the head (19.5%) and ankle (14.3%)[57] were the most common injury sites but at the 2006 RWC(W), the neck/cervical spine and knee(14.3%)[285] were the most common injury sites.

Only a few studies[46, 257, 302] reporting on women's rugby-15s match injuries identified the injury region but did not report the injury site. However, these varied by participation level with the head and neck (collegiate: 6.0 [95% CI: 1.0 to 7.0] per 10,000 athlete-exposure),[257] and lower limb (national: 3.0 [95% CI: 1.8 to 5.0] per 1,000 player-hr [match and training];[46] RWC(W): 61.5 [95% CI: 46.3 to 76.8] per 1,000 match-hr[302]) being the most common injury regions reported. The lower limb was the most common injury region reported in the majority of studies.[46, 79, 175, 285, 302]

For women's rugby-7s, the most common injury site was the knee (7.3 [95% CI: 4.7 to 11.5];[217] and 11.7 [95% CI: 7.1 to 19.4][101] per 1,000 match-hr). Ma et al. also reported that the head recorded an equal number of injuries (7.3 [95% CI: 4.7 to 11.5] per 1,000 match-hr)[217] as the knee over the duration of the study. When assessed by amateur U19 and elite-national players, the most common injury sites varied, with non-elite/amateur (U19) players recording the head/face (8.4 [95% CI: 95% CI:5.3 to 13.4] per 1,000 match-hr) and knee (6.6 [95% CI: 3.9 to 11.1] per 1,000 match-hr) while elite-national players recorded the knee and shoulder (10.9 [95% CI: 4.5 to 26.1] per 1,000 match-hr) as the most common injury sites. The lower limb (19.3 [95% CI: 14.6 to 25.5][217]; and 45.3 [95% CI: 35.0 to 58.6][101] per 1,000 match-hr) was the most common injury region reported for women's rugby-7s match activities.

Injury type

The injury types varied by participation level and not all studies reported all injury types with some studies[19, 57] only reporting the most common injuries. In reporting on rugby-15s, Bird et al.[19] reported that strains/sprains were the most common match and training injury types, but the data were not separated into male and female participants. At the high school level of participation,[57] fractures (16.0%) and concussions (15.8%) were the most common injury types. At the collegiate level of participation, strains/sprains (6.6 [95% CI: 5.4 to 8.0] per 1,000 player-game-hr)[175] were the most common injury types. Injuries commonly reported at the national level of participation were ankle sprains (1.4 [95% CI: 0.7 to 3.0] per 1,000 player-hr [match and training]) and concussions (0.8 [95% CI: 0.3 to 2.1] per 1,000 player-hr [match and training]).[46] For players at the international level of participation, medial collateral ligament ankle sprains (0.5 [95% CI: 0.2 to 1.4] per 1,000 player-hr [match and training]), calf strains and acromioclavicular sprains (0.4 [95% CI: 0.1 to 1.3] per 1,000 player-hr [match and training]) were the most common injury types.[79]

Data for the RWC(W) showed that sprains (13.3 [95% CI: 8.2 to 21.8] per 1,000 match-hr;[285] 15.5 [95% CI: 9.6 to 24.9] per 1,000 match-hr[302]) and strains (14.2 [95% CI: 8.8 to 22.8] per 1,000 match-hr;[285] 10.0 [95% CI: 5.5 to 18.1] per 1,000 match-hr[302]) were the most common injury types. Concussions in the RWC(W) were reported at 6.2 per 1,000 match-hr[285] and as 10% of the total injuries recorded.[302]

In women's rugby-7s, the most common injury types were sprains (16.2 [95% CI: 4.2 to 14.5] per 1,000 match-hr), and; fractures and concussions (11.7 [95% CI: 7.1 to 19.4] per 1,000 match-hr) at the amateur/U19 and elite/national competitions.[217] At the elite level of rugby-7s participation, the most common injury types were sprains (32.0 [95% CI: 23.6 to 43.5] per 1,000 match-hr), concussions (14.9 [95% CI: 9.5 to 23.3] per 1,000 match-hr) and dislocations (7.8 [95% CI: 4.2 to 14.5] per 1,000 match-hr).[101]

Injury cause

Some of the studies[19, 46, 79, 257] reported on injury cause. Of those studies[57, 175, 285, 302] that reported on women's rugby-15s, the tackle was the cause of most injuries. Four studies[57, 175, 285, 302] reported on whether the injury occurred to the tackler or the ball carrier. The ball carrier recorded more injuries than the tackler at the collegiate (5.5 [95% CI: 4.5 to 6.8] vs. 3.5 [95% CI: 2.7 to 4.6] per 1,000 player-game-hr; $\chi^2_{(1)}$=6.7; p=0.0095),[175] and RWC(W) (14.5 [95% CI: 8.9 to 23.7] vs. 10.9 [95% CI: 6.2 to 19.2] per 1,000 match-hr; $\chi^2_{(1)}$=0.6; p=0.4497;[285] 11.8 [95% CI: 6.9 to 20.4] vs. 1.8 [95% CI: 0.5 to 7.3] per 1,000 match-hr; $\chi^2_{(1)}$=8.1; p=0.0045)[302] levels of participation. The tackler recorded more injuries than the ball carrier at the high school (32.5% vs. 28.6%)[57] level of participation. One study[285] did not report on the injury cause. Kerr et al.[175] reported that the tackler recorded more injuries (1.2 [95% CI: 0.8 to 1.8] vs. 1.0 [95% CI: 0.7 to 1.5] per 1,000 AE; $\chi^2_{(1)}$=0.5; p=0.4922) than the ball carrier in training activities. Non-contact injuries accounted for between 8.3%[285] and 14.8%[79] of total rugby-15s match injuries and 38.9%[175] of rugby-15s training injuries.

Only Ma et al.[217] reported injury cause for women's rugby-7s match activities. The most common injury cause was the tackle, with the ball carrier recording more injuries (18.5 [95% CI:14.0 to 24.6] vs. 13.9 [95% CI:10.0 to 19.3] per 1,000 match-hr; $\chi^2_{(1)}$=1.7; p=0.1904) when compared with the tackler. Non-contact injuries accounted for between 3.8% and 16.7%[101, 217] of the total injuries recorded in rugby-7s.

Table 6: Injury severity definitions utilised in studies reporting on injuries in women's rugby-15s and rugby-7s.

Reference	Non-missed participation	Minor/mild	Moderate	Major
Bird et al.[19]	-	AIS - 1	AIS - 2	AIS - 3
Carson et al.[46]	-	< 1 week out of practice or game situations	1 to 3 weeks out of practice or game situations	> 3 weeks out of practice or game situations. Includes season ending injuries
Doyle et al.[79]	Player was able to return to the game or training in which the injury occurred	Player missed 1 week	Player missed 2 weeks	Player missed more than 2 weeks
Collins et al.[57]	-	< 10 days missed	10-21 days missed	> 21 days missed
Kerr et al.[175]	1 day	2-3 days	4-7 days	> 7 days
Ma et al.[217] Fuller et al.[101] Schick et al.[285] Taylor et al.[302]	No days (0) lost; slight (0-1 day of playing time lost); minimal (2-3 days of playing time lost)	Mild (4-7 days of playing time lost)	Moderate (8-28 days of playing time lost)	Severe (>28 days of playing time lost)

AIS = Abbreviated Injury Scale

Injury severity

The injury severity definitions varied across studies (see Table 6). The most commonly utilized injury severity classification was based on the 2007 consensus statement.[98] Since the publication of the statement, only time-loss injuries have been reported.[101, 217, 285, 302] The most common injury severity for women's rugby-15s participants at the high school level of participation was minor (<10 days' time loss) which accounted for more than half of the injuries recorded (55.9%) while severe (>21 days' time loss) accounted for less (23.4%).[57] At the international level of participation, severe (>2 weeks' time loss) injuries accounted for the majority of the injuries recorded (44%) while mild (>1 week <2 weeks' time loss) accounted for less (37%).[79] This was similar for studies reporting on collegiate (major: >7 days' time loss: 51%; minor: 1-7 days' time loss: 45%)[175] and RWC(W) (severe: >28 days' time loss; 10.9 per 1,000 match-hr; minimal: 2-3 days' time loss; 9.1 per 1,000 match-hr)[302] levels of participation. Although two studies[101, 217] on women's rugby-7s reported severity as 'mean days absent', 'mean severity, days' and 'median severity of injuries, days', these do not align with the reporting of injury severity as defined by the consensus statement on injury definitions and data collection procedures for studies on injuries in rugby union.[98]

Match period

Three studies[79, 285, 302] reported injuries by match period. At the international level of participation there were more injuries recorded during the second (1.3 [95% CI: 0.7 to 2.5] vs. 1.1 [95% CI: 0.5 to 2.2] per 1,000 total (match and training) rugby hr; $\chi^2_{(1)}$=0.2; p=0.6374)[79] when compared with the first half of matches. There were more injuries recorded in the first (40.0 [95% CI: 24.0 to 56.0] vs. 35.0 [95% CI: 20.0 to 50.0] per 1,000 match-hr; $\chi^2_{(1)}$=0.2; p=0.6547) than the second half of matches at the 2006 RWC(W)[285] but this differed to the 2010 RWC(W),[302] where there were more injuries recorded in the second (41.8 [95% CI: 24.7 to 58.9] vs 29.1 [95% CI: 14.8 to 43.3] per 1,000 match-hr; $\chi^2_{(1)}$=1.3; p=0.2623) when compared to the first half of matches. Additionally, in rugby-15s matches that have had the match halves broken down into quarters, it has been found that during the fourth quarter of matches (50.9 [95% CI: 24.2 to 77.6] per 1,000 match-hr) the highest incidence of injuries occurs. One study[101] reporting on women's elite rugby-7s did not report the match period when injuries occurred and the other rugby-7s study[217] combined elite and non-elite data and reported that more injuries occurred in the second (54% vs. 46%) than in the first half of matches.

Discussion

This study is the first to systematically review the incidence of injuries in women's rugby-15s and rugby-7s match and training activities. The results of this systematic review showed that the incidence of injuries in rugby-15s varied from 3.6 per 1,000 playing (match and training)-hr[79] to 37.5 per 1,000 match-hr,[285] which was lower than professional men's rugby-15s (81 per 1,000 match-hr)[322] but similar to children and adolescent rugby-15s pooled injury incidence (26.7 per 1,000 match-hr).[94] When pooled, the incidence of injury for rugby-15s was less at 19.6 per 1,000 match-hr. Regarding women's rugby-7s, the incidence of injury varied between 46.3[217] and the pooled incidence of 95.4[101] per 1,000 match-hr and this was less than the pooled incidence of elite men's rugby-7s injury incidence (109.4 per 1,000 match-hr).[101] When pooled, the incidence of injury for rugby-7s was 62.5 per 1,000 match-hr.

Data collection

The use of player recall of injuries has been previously reported[105, 311] to have some bias as recall accuracy reportedly declines as the level of detail requested is increased. Although the studies included in this review contacted the players directly[19, 217] or reviewed injury records,[57, 175, 217, 257] there is the risk that the information provided was inaccurate in detail or that not all injuries were reported or recorded if the participant did not present for assessment. If the contact between the medical professional recording the information and the player was infrequent, then there would be increased risk that the injury may have been missed or not diagnosed.[307] The accuracy of the injury diagnosis in these types of studies may be questioned especially where there were no trained healthcare follow-up assessments undertaken.[332] It is presumed that, at higher levels of participation the data accuracy would be better when compared with amateur and junior levels of participation where medical support may be less consistent and injury information would be dependent on the skill of the observer.[307] In addition to this, variations in the incidence of injuries are often the result of data obtained from a relatively small number of players and teams,[136, 147] often over a limited time frame[156] and by people with varying skills as a data collector.[91]

Injury definition

It is important to note that some injury definitions utilised a missed match or time-loss definition and consequently only reported injuries that resulted in a match being missed.[30, 146] Conversely, other studies reported all-encompassing or medical treatment injuries that occurred as a result of match participation.[30, 146] Both these types of injury definitions have advantages and disadvantages associated with them such as production of a large database of injuries (all-encompassing definition) and easy to implement for matches missed (missed-match definition).[30] The studies published since the publication of the 2007 consensus statement on injury definition and data collection procedures[98] can be compared as they have utilised a similar injury definition.

Although time-loss is identified as the ‘gold standard’ in reporting injuries in rugby union, transient or minor injuries still create an impact on the financial resources of teams and participation of players.[202] It has been identified that non-time-loss injuries can often account for between 72% and 95% of the total injuries that occur.[202] In reporting on women's rugby-7s, Ma et al.[217] identified an incidence of 46.3 (39.9 to 58.7) per 1,000 match-hr time loss injuries that accounted for 48.7% (120) of the total (253) injuries that occurred over the duration of the tournament. These injuries, despite not directly affecting the player's participation in matches, are important as they can limit the player's ability to compete in the current match, require ongoing support, and having a direct and indirect economic impact[146, 202] through areas such as lost employment and rehabilitation.

Pooled analysis

The pooled incidence of injuries in women's rugby-15s matches (19.6 per 1,000 player-hr) was lower than the reported pooled injury incidence of senior men's professional (81 per 1,000 player-hr)[322] amateur male (46.8 per 1,000 match-hr)[332] and for children and adolescent (26.7 per 1,000 player-hr)[94] participants. When compared to missed-match (7 days' absence from games) injuries, the pooled injury incidence for women's rugby-15s matches was higher than at the pooled incidence reported for children and adolescent (10.3 [95% CI: 6.0 to 17.7] per 1,000 player-hr)[94] participants. This was similarly seen in the rugby-7s competitions where the pooled women's injury incidence was lower (95.4 vs. 109.4 per 1,000 player-hr) than the men's pooled injury incidence yet they participated in the same competitions.[101] Reporting on the rugby-7s international elite competitions, Fuller et al.[101] identified that the incidence of injury in rugby-7s world tournament series (88.5 to 109.4 per 1,000 match-hr) was higher than at the Olympics (71.1 per 1,000 match-hr) and this may have been related to differences in the tournaments undertaken, the number of matches played or the pre-competition training loads when comparing women's international elite competitions preparation and participation.

Participation level

Similar to previous studies,[161, 301, 322, 332] the incidence of injuries increased with the higher level of competition. Possible explanations for the increased incidence of injuries at higher levels of participation include more ball-in-play time, greater distances covered at relatively fast running times (> $5 m.s^{-1}$), more efficient injury reporting, increased size and strength of players, and higher levels of competitiveness.[33, 161, 267, 301] In addition, data collected at the international level of participation are usually obtained from a tournament setting instead of throughout a seasonal competition and this may be inherently different.[322]

As noted in other rugby codes, it has been suggested that the differences between men's and women's rugby-15s and rugby-7s injury incidence may be related to physiological aspects. Women reportedly demonstrate slower speed and less agility, lower muscular power, lower estimated maximal aerobic power and a greater relative mass and skinfold thickness when compared with men.[196] It has been hypothesized by one research group that women participate in contact sports such as rugby-15s and rugby-7s with less aggression[46] when compared with men. However, in contrast, a few studies[256, 275, 333] have reported that women have similar attitudes to men in terms of sports participation in areas such as aggression, physical danger, and injury. Consequently, the differences between the men's and women's injury incidence may be more related to the recent increase in the popularity of women's rugby-15s and rugby-7s and its subsequent uptake.[68] For example, 21,000 girls across 138 nations were introduced to the game in 2014 and female participation increased from 1.5 million in 2013 to 1.77 million in 2014.[327] This number increased again to an estimated 2 million female participants across 110 different countries by 2016.[328]

Although the studies included in this review ranged from community to elite levels of participation, there were no prospective observational studies at the amateur club and representative levels of participation for rugby-15s. As noted in other rugby codes, this may be related to the unavailability of specialized medical staff at the event or through the club facilities.[107, 109] Recording of injuries is often limited to interested personnel or may not occur at all. Amateur rugby-15s teams may also not have direct access to medical services,[106, 109] or have financial restrictions limiting access to rehabilitation providers,[186] whereas other levels of participation have a physiotherapist and/or team physician present when they play.[107, 108] At the professional level of participation, teams are supported with, and have full access to, specialized rehabilitation services.[106]

Player position

Some studies[46, 57, 257, 302] included in this review provided player position information when reporting match and training injuries. Forwards recorded more injuries than backs in some,[175, 285] of the studies, which was similar to previous studies where Forwards[15, 17, 23, 31, 70, 161, 301] recorded more injuries than Backs.[17, 33-35, 52, 244, 294] It must be noted that one study[285] reported that Backs recorded more injuries than Forwards (37.5 vs. 35.9 per 1,000 match-hr), and that Backs recorded more injuries than Forwards at a different rate (42.2 vs. 39.3 per 1,000 match-hr). When the data provided[285] were recalculated, it was identified that Forwards recorded more injuries than Backs (41.1 vs. 32.8 per 1,000 match-hr). The higher contact and collision demands in rugby-15s of Forwards,[74, 332] combined with the greater body mass and increased momentum,[265, 268] have been suggested as possible explanations for the higher incidence of injury in Forwards than Backs.[31] For those studies that reported that Backs recorded more injuries than Forwards, a possible suggestion for the reversal of injury trends may be the increase in 'ball-in-play' time that has occurred as a result of law changes and match tactics.[33] This may have been evident in the study of the RWC(W),[302] where Backs sustained more injuries than in earlier studies[79, 175, 285] that reported Forwards had more injuries. However, changes in match tactics and playing intensity, for example the ball being in play for longer periods of time, higher skill levels and the game being played at a faster pace with fewer breaks and harder tackling[15, 301] would be expected to be associated with an increase in injuries.

Rugby-7s is a fast-paced physical game[101] resulting in different injury rates and patterns when compared with rugby-15s.[217] Although the team consists of three Forwards (two props, one hooker) and four Backs (one scrumhalf, one fly half, one centre, one wing),[217] the published results are grouped as either Forwards or Backs. As a result, the identification of the specific player position most at risk of an injury is limited to player group. Only one study[217] reported rugby-7s player group with Backs recording more injuries than Forwards in the elite (n=9 vs. n=6) and non-elite (n=63 vs. n=37 [n=5 no position reported]) levels of participation.

Injury site and type

The injury region most commonly reported was the lower limb (consisting of the knee, lower leg, ankle, foot, and toes). This was similar to previous rugby-15s injury studies[36, 254, 322, 332] where the lower limb sustained the most injuries. Despite this, the most commonly reported injury site was the head/face (consisting of the head, face, nose, eye, and mouth), which was in conflict with male rugby-15s injury studies[17, 36, 332] where the knee was the most commonly reported injury site. Lower limb injuries appeared to be disproportionately severe,[36] especially knee joint injuries such as the medial collateral ligament, chondral, meniscal and patella tendon injuries. The finding that strains/sprains were the most common injury type was not unexpected. In a meta-analysis of senior men's professional[322] and amateur[332] rugby-15s it was reported that muscle/tendon and joint (non-bone)/ligament (also termed strains and sprains) injures were the most common. Thigh haematomas and hamstring injuries have been reported[36, 95] to be the most common injuries in rugby-15s; however, there was insufficient information in the reviewed rugby-15s studies to confirm this. In rugby-7s, ligament sprains, fractures and concussions were the most commonly recorded injury types.[217] The knee and head/face were the most common injury sites and the lower limb was the most common injury region reported.[217] Although there appear to be similar injury sites and types when comparing rugby-15s with rugby-7s based on the available published studies, this may not be the case. There have been law changes in the modern version of rugby-15s and these changes may not coincide with when the reviewed studies were completed. In addition, there is a paucity of studies on women's rugby-7s, meaning that a complete comparison is not possible.

Injury cause

The finding that the tackle was the most common phase of play when injuries occur is expected as the tackle is the most common event in rugby-15s and rugby-7s matches.[95] This finding is similar to other studies[15, 17, 19, 23, 33, 84, 95, 122, 123, 142, 152, 153, 161, 266, 301, 332] reporting on rugby-15s injuries. In men's professional rugby-15s, the tackle has accounted for up to 58% of all game related injuries and resulted in the highest injury severity per 1000 match-hr.[95] This was similar to the findings of this review for women where the tackle accounted for 38%[302] to 62%[285] of injuries in women's rugby-15s matches and 70%[217] of the injuries in women's rugby-7s.

Different levels of participation have different tackle characteristics with more skilled and older players engaged in a higher proportion of shoulder and smother tackles having a higher risk of an injury occurring. Tackles involving two tacklers and tackling simultaneously were associated with the greatest incidence of injury to both the tackler and ball carrier.[228] This may have been the case with the participants in the different levels of participation in the studies included in this review. The finding that the ball carrier recorded more injuries in some[175, 217, 285, 302] of the studies included in this review was similar to a recent study[332] of adolescent rugby players. Lower levels of participation resulted in a different injury risk and this may be the same with the studies under review.

Match period

The results of this review vary in terms of the match time when the most injuries occur. Two studies[79, 302] reported that more injuries occurred in the second half of matches; conversely, one study[285] reported more injuries in the first half of matches. As there is a paucity of data to report on when injuries most commonly occur in women's rugby-15s matches it is unclear if the incidence of injuries occurs differently when compared with men's rugby-15s injury match times. When compared with previous studies reporting on male rugby-15s participation most of the studies[15, 17, 31, 70, 153] included in this review reported that more than half of the match injuries occurred in the second half of matches. It has also been reported[31, 70] that more injuries were recorded in the final quarter of matches than in any other match quarters. In regard to women's rugby-7s, there is a lack of evidence to make a conclusive decision on the match period where injuries most commonly occur. Studies that reported the incidence of training injuries did not report when these occurred during the training activity.

Limitations

The low number and moderate quality of the ten studies included in this systematic review was a limitation. The variation in the injury definitions and the methodological differences utilised resulted in only four studies being included in the pooled analysis for women's rugby-15s and two studies in the rugby-7s analysis. Although some of the published studies[57, 101, 175, 217, 285, 302] took place after the consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union,[98] none of them complied with all of the reporting procedures outlined; however, they did utilize a variation of these procedures in terms of injury classification. For example, there were different injury severity definitions utilised with one study reporting a mild/minor injury as two-three days while other studies utilised a one-week definition. In addition, the reported injury incidence variations from a number per 100 games or practices, per 10,000 AE, per 1,000 rugby [match and training]-hr and per 1,000 match-hr further limited the inter-study analysis. Some studies combined match and training injuries, further limiting inter-study comparisons.

Most of the studies included in this review provided all the information to enable the different areas under review to be conducted fully and this needs to be considered with any further analyses. With regard to the pooled analysis conducted, assumptions of the pooled data for rugby-7s is limited due to the lack of studies, whilst the pooled data for rugby-15s is further limited by data being collected by non-healthcare providers (coaches and administrators).[175] The current literature on rugby is further limited, if there is combining of format exposures (i.e. rugby-7s and rugby-15s) injury incidence and/or combining of match and training data and not adhering to the consensus statement.[98] Future studies in women's rugby-15s and rugby-7s should utilise the consensus statement[98] for the reporting of rugby injuries and to assist in interstudy companions.

Future research

As identified through this review, there is a paucity of published literature reporting on women's rugby-15s and rugby-7s injury epidemiology. Areas such as inter-study comparisons are limited by the different methodological approaches and definitions utilised. The publication of the consensus for data collection in rugby union studies [98] provides for a standardised approach, and if future studies undertake to utilise the reporting recommendations identified this would help to assist with the identification of the injury site, type, location, severity and mechanism of injury that occurs within women's rugby-15s and rugby-7s. This includes using a reporting modality such as per 1,000 match-hr or training-hr to enable inter-study comparisons and pooled analysis. The studies included in this review represented World Cup, Olympic, national, international, collegiate, high school, and community participants, but there have been no studies reporting on the amateur domestic and regional competitions or training activities prospectively; and these areas should be considered for future research.

Typically, most of the studies included in this review were undertaken over a single season or competition, limiting the identification of injury trends, and future longitudinal studies should be encouraged in women's rugby-15s and rugby-7s activities. Another research consideration is the reporting of concussion in women's rugby-15s and rugby-7s. There is an increasing awareness of the issue of concussion in rugby and a standardised approach to the assessment of this injury in women rugby participants is necessary in terms of assessment tools, definition, and management. Although the data collection methods appear to be similar for males and females, there are differences in terms of injury risk and recovery when comparing the sexes.[135, 299] As such, some aspects unique to females may be important for future research being undertaken, such as the relationship between the phase of the menstrual cycle and the incidence of injuries.[78, 93, 234, 325, 330]

Conclusions

The primary objective of this review was to provide a summary of descriptive data on women's rugby-15s and rugby-7s injury epidemiology. The pooled incidence of match injuries in women's rugby-15s and rugby-7s was higher in rugby-7s (62.5 per 1,000 match-hr versus 19.6 per 1,000 match-hr) than in rugby-15s. Pooled match injuries were higher than pooled training injuries (1.5 per 1,000 training-hr) for women's rugby-15s. All pooled injury incidences for women's rugby-15s and rugby-7s were less than for men's rugby-15s and rugby-7s at the comparable participation level. The tackle resulted in the most injuries at all levels of participation for both rugby-15s and rugby-7s. The head/face was the most commonly reported injury site. Lower limb injuries appeared to be disproportionately severe, especially knee joint injuries. In rugby-7s, Backs recorded more injuries than Forwards, and the incidence of training injuries ranged from 0.95 to 2.2 per 1,000 player training-hr. Undertaking injury surveillance at all levels of women's rugby-15s and rugby-7s match and training participation will assist with understanding the nature and cause of such injuries, and the events associated with their occurrence. As there were no studies identified that reported on club-based and regional representative levels of women's rugby-15s or rugby 7s, future studies at these levels are warranted.

Key Points:

1. The pooled incidence of match injuries was higher in women's rugby-7s than in women's rugby-15s (62.5 per 1,000 match-hr versus 19.6 per 1,000 match-hr).
2. Pooled match injuries rates (19.6 per 1,000 match-hr) were higher than pooled training injuries (1.5 per 1,000 training-hr) for women's rugby-15s.
3. All pooled injury incidences for women's rugby-15s and rugby-7s were less than for men's rugby-15s and rugby-7s at a comparable participation level.
4. The tackle resulted in the most injuries at all levels of participation.
5. The head/face was the most commonly reported injury site.

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STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Douglas Alistair King
Name/title of Primary Supervisor:	A/Prof Matt Barnes
In which chapter is the manuscript /published work:	Chapter 2

Please select one of the following three options:

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- Please provide the full reference of the Research Output:

King, D., Hume, P.A., Cummins, C., Pearce, A.J., Clark, T.N., Foskett, A. & Barnes, M.J. Match and training injuries in women's rugby union: A systematic review of published studies. Sports Medicine, 49(10): 1559-1574

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Candidate's Signature:	Doug King Digitally signed by Doug King Date: 2021.01.28 11:15:06 +13'00'
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Date:	28-Jan-2021

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Chapter 4: Training injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons

This chapter comprises the following paper published in *Journal of Science and Medicine in Sport*

Reference:

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Training injury incidence in an amateur women's rugby team in New Zealand over two consecutive seasons. *Journal of Science and Medicine in Sport*, 2020. **24**(6): 544-548

Overview

Objectives: To describe the training injury incidence in amateur women's rugby union in New Zealand over two consecutive seasons.

Methods: A prospective cohort observational study of 69 amateur women's rugby 15s team players. Training exposure and training injury incidence were calculated.

Results: The 38 training injuries resulted in a total injury incidence of 11.4 (8.3 to 15.6) per 1,000 training hrs. There were 12 injuries that resulted in a time-loss injury incidence of 3.6 (95% CI: 2.0 to 6.3) per 1,000 training-hrs. Forwards recorded more total (RR: 1.8 [95% CI: 0.9 to 3.5]; *p*=0.0516) and time-loss (RR: 2.0 [95% CI: 0.6 to 6.6]; *p*=0.2482) injuries than Backs. The tackle was the most common injury cause for total (3.0 [95% CI: 1.6 to 5.6] per 1,000 training-hrs.) injuries, but collisions (1.5 [95% CI: 0.6 to 3.6] per 1,000 training-hrs.) with the ground or another person were the most common cause for time-loss injuries. The training injuries occurred most often to the lower limb and during the latter part of training sessions. These injuries were mostly minor in nature resulting in minimal time-loss away from training.

Discussion: The time-loss injury incidence (3.6 per 1,000 training-hrs.) for the amateur women's rugby 15s team players was higher than that reported for National (1.2 per 1,000 training-hrs.) and Rugby World Cup for women (0.2 to 3.0 per 1,000 training-hrs.) competitions.

Conclusion: The training injury incidence in amateur women's rugby union in New Zealand was higher than that reported for national and international rugby union injury incidences.

Introduction

The game of rugby union has gained international popularity with approximately 8.5 million registered players in over 121 countries worldwide.[188] As rugby union is a collision sport, players are exposed to repeat high-intensity activities (e.g. running, tackling, rucks, mauls, passing and sprinting) interspersed with short bouts of low intensity activity (e.g. jogging and walking).[58] As a consequence of the participation of players in match and training activities, there is an increased risk of musculoskeletal injuries occurring.[58] In addition to this, there are biomechanical factors to consider with females reportedly having lower physiological capacities (e.g. reduced speed and less agility, lower muscular strength and power, and lower estimated maximal aerobic power) when compared with males, placing them at a higher injury risk.[196]

There is a paucity of studies reporting on women's rugby-15s training injuries. In a recent systematic review and pooled analysis,[188] the pooled training injury incidence was 1.5 (95% CI: 0.8 to 2.2)[188] per 1,000 training-hrs, but this varied from 0.2[302] (2010 Rugby World Cup for women [RWC(W)])to 3.0[285] (2006 RWC(W)) injuries per 1,000 training-hrs and 5.5[175] (Collegiate) per 1,000 athletic-exposures (AE). These studies were typically undertaken over a tournament[285, 302] or a single[46, 57, 175] competition season, utilising different methodologies that make comparisons difficult.[188] Although women's rugby-15s has grown in participation over the past few decades worldwide,[188] the number of published studies reporting on these activities has not been at the same rate. In particular, there are no amateur women rugby-15s studies from New Zealand that have been published to date, despite this being the base for the world champion 'Black Ferns'.[68] Therefore, the aim of this study was to report the incidence, site, type and timing of amateur women's rugby-15s training injuries over two consecutive competition seasons and to compare these with published studies on women's contact and collision sports.

Methods

A prospective cohort descriptive study was undertaken to document the training injury incidence occurring in an amateur women's rugby-15s team. A total of 69 (age: 26.5 ±7.4 years [range: 17.6 to 48.5 years]; Height: 1.67 m ±0.08m [range 1.50-1.80 m]; mass 87.1 kg ±18.9 [range 50-127 kgs] years playing experience 4.3 ±4.2 years [range 0-18 years]) amateur women participants were enrolled from the same team over two consecutive years participating in a women's rugby union club-based competition. A total of 34 players participated in the first season and 35 players competed in the second season. A total of 22 players participated in both competition seasons. All players were considered amateur, as they received no remuneration for participating in rugby union activities and derived their main source of income from other employment activities.

The injury definition utilised for this study was "*Any physical complaint, which is caused by a transfer of energy which exceeds the ability of the body's ability to maintain its structural and/or functional integrity, that is sustained by a player during rugby trainings, irrespective of the need for medical attention or time-loss from rugby activities.* "[98]

Players were categorised according to their playing group.[45] This group was: (1a) Forwards (loose-head prop, hooker, tight-head prop, left lock, right lock, blind-side flanker, open-side flanker, and number eight) and (1b) Backs (halfback, fly-half, left wing, inside centre, outside centre, right wing, and full back). The hooker was included in the Back Row Forward's due to their roving style of play.[74] This would most accurately reflect the positions with similar match demands and enable comparisons to be undertaken.

Only team-organised field-based training sessions were included in this study. This was initially three times per week (Dec to Feb) then twice a week until the competition season finished. All training sessions were 90 minutes in duration. Players were encouraged to undertake their own individual gym and aerobic conditioning training sessions on non-team field-based training days, and these were not included in the study. All field-based training sessions were undertaken utilising RugbySmart warm-up and cool-down activities (https://www.rugbysmart.co.nz) and the activities undertaken for the training were coach directed. Training exposure was calculated as to the duration time of every individual player that attended training from the time, they attended to the cessation of the training session.

The team medic (DK) was a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment, and management. Player medical history, including previous concussion history were collected in the pre-season period before the player undertook any training activity.[187] Injury data were collected from all team-based training activities the team participated in. Injury rates were determined using previously described methods.[30, 313] All injuries were recorded on a standardized injury reporting form, regardless of severity. Recorded details of each injury included, date of onset of injury, date of return to training, location, type, player position, player role (forward, back), training period (1st half 0-45 min; 2nd half 46-90 min) and Orchard Sports Injury Code (v10.1),[252] to enable further analysis for total and time-loss analysis. If more than one injury occurred to an injury site, these were recorded individually as injury type. As a result, there were more injury types than total injuries recorded. Severity of injuries were recorded as mean (days-absence) and also within grouped severity time-loss values (slight: 0-1 days; minimal: 2-3 days, mild: 4-7 days, moderate: 8-28 days and severe: >28 days).[98] Both total and time-loss injuries were recorded and reported throughout the study. This was undertaken to provide a true picture of the injury incidence in women's rugby union.[146] Time-loss injuries were classified as those injuries that resulted in the player being unable to take a full part in future rugby training or match activities.[98] In terms of this study, this was any injury that was classified as mild, moderate or severe. Injuries classified as slight or minimal were not classified as time-loss as no matches were missed and these injuries did not meet the time-loss definition.[98]

Statistical analysis

All the data collected were entered into a Microsoft Excel spreadsheet and analysed with Statistical Package for Social Sciences for Windows (SPSS; V25.0.0). Training exposure was calculated based on the number of players present at the training session being exposed for 90 min, positional groups exposure was based on the number of players in the group (i.e., Forwards and Backs). Training injury incidence was calculated as the number of injuries per 1,000 training-hrs, with 95% confidence intervals (CI's) for total and time-loss injuries. A one-sample chi-squared (χ^2) test was used to determine whether the observed injury frequency was significantly different from the expected injury frequency by competition year and for total training injuries recorded. Cohen's effect size (*d*) were utilised to calculate practically meaningful differences between playing positions and injury sites. Effect sizes of <0.19, 0.20-0.60, 0.61-1.20 and >1.20 were considered trivial, small, moderate, and large, respectively.[155] To compare between injury rates per year and for total injuries recorded, risk ratios (RR's) were used. RRs were assumed to be significant at $p<0.05$.

Results

Over the study 69 (age: 26.5 ±7.4 yrs.; stature: 1.65 ±0.72 m; mass: 86.6 ±15.9 kg; playing experience 4.3 ±4.2 yrs.) players participated (41 Forwards; 28 Backs). There were 38 total training injuries (11.4 [95% CI: 8.3 to 15.6] per 1,000 training-hrs and 12 time-loss injuries (3.6 [95% CI: 2.0 to 6.3] per 1,000 training-hrs) recorded (see Table 7). There were no observable differences between total (24 vs. 14; $\chi^2_{(1)}=3.1$; $p=0.0769$) and time-loss (7 vs. 5; $\chi^2_{(1)}=0.4$; $p=0.5094$) training injuries recorded in 2019 compared with 2018. There were more total (20 vs. 14; $\chi^2_{(1)}=1.1$; $p=0.3035$) and time-loss (5.7 vs. 5.0; $\chi^2_{(1)}=0.0$; $p=0.8305$) injuries expected in 2018 than actual injuries recorded. However, there were fewer total (18 vs. 24; $\chi^2_{(1)}$=11.3; p=0.0008) and time-loss (6.3 vs. 7.0; $\chi^2_{(1)}$=0.0; p=0.8478) injuries expected in 2019 than actual injuries recorded.

Forwards recorded more total (7.5 [95% CI: 5.1 to 11.1] vs. 3.9 (95% 2.3 to 6.7) per 1,000 training-hrs; RR: 1.8 [95% CI: 0.9 to 3.5]; p=0.0516) and time-loss (2.4 [95% CI: 1.2 to 4.8] vs. 1.2 [95% CI: 0.6 to 3.6] per 1,000 training-hrs; RR: 2.0 [95% CI: 0.6 to 6.6]; p=0.2482) injuries than Backs, but this was not significant (see Table 8). The lower limb sustained more injuries (8.4 [95% CI: 5.8 to 12.1] per 1,000 training-hrs.) than the upper limb (2.4 [95% CI: 1.2 to 4.8] per 1,000 training-hrs; RR: 3.5 [95% CI: 1.6 to 7.7];

Table 7: Total and time-loss injuries, injury rate, injuries per training and training minutes per injury in an amateur domestic women's rugby union team in New Zealand over two consecutive years. Data reported as number of injuries, rates per 1,000 match hours with 95% confidence intervals.

	Total injuries			Time-Loss training injuries		
	2018	**2019**	**Total**	**2018**	**2019**	**Total**
Injuries observed, n	14	24	38	5	7	12
Injuries expected, n	20	18	38	5.7	6.3	12
Injury rates per 1,000 training-hrs, (95% CI)	8.2 (4.9-13.8)	14.7 (9.9-22.0)	11.4 (8.3-15.6)	2.9 (1.2-7.0)	4.3 (2.0-9.0)	3.6 (2.0-6.3)
No. trainings played, n	60	54	114	60	54	114
Exposure hrs, n	1,709.4	1,630.1	3,339.5	1,709.4	1,630.1	3,339.5
Hrs per injury, m (95% CI)	122.1 (72.3-206.2)[b]	67.9 (45.5-101.3)[a]	87.9 (63.9-120.8)	341.9 (142.3-821.4)[b]	232.9 (111.0-488.5)[a]	278.3 (158.0-490.0)
Total no. injuries per training, m (95% CI)	0.2 (0.1-0.4)	0.4 (0.3-0.7)	0.3 (0.2-0.5)	0.1 (0.1-0.2)	0.1 (0.1-0.3)	0.1 (0.1-0.2)
Player appearances per injury, m (95% CI)	64.3 (38.1-108.5)[b]	33.8 (22.6-50.4)[a]	45.0 (32.7-61.8)	180.0 (74.9-423.5)[b]	115.7 (55.2-242.7)[a]	142.5 (80.9-250.9)
Training minutes played per injury, m (95% CI)	342.9 (203.1-578.9)[b]	180.0 (120.6-268.6)[a]	240.0 (174.6-329.8)	960.0 (399.6-2,306.5)[b]	617.1 (294.2-1,294.5)[a]	760.0 (431.6-1,338.3)

n = number; m = median; CI = Confidence Interval; SD = Standard Deviation Significant difference (p<0.05) than (a) = 2018; (b) = 2019.

p=0.0009), head/neck (1.5 [95% CI: 0.6 to 3.6] per 1,000 training-hrs; RR: 5.6 [95% CI: 2.2 to 14.5]; *p*=0.0001) and chest/back (0.3 [95% CI: 0.0 to 2.1] per 1,000 training-hrs; RR: 28.0 [95% CI: 3.8 to 205.7]; *p*<0.0001) injury sites. As a result, the lower limb recorded the highest total days-lost (170 days) with a mean of 7.4 ±12.5 (99.4 [95% CI: 85.6 to 115.6] per 1,000 training-hrs) days per injury. The ankle recorded the highest total days-lost (68 days) with a mean of 12.0 ±23.6 (39.8 [95% CI: 31.4 to 50.5] per 1,000 training-hrs) days-lost per injury.

There were significantly more total training injuries recorded as strains and sprains (8.7 [95% CI: 6.0 to 12.5] per 1,000 training-hrs.) than dislocations (1.8 [95% CI: 0.8 to 4.0] per 1,000 training-hrs; RR: 4.8 [95% CI: 2.0 to 11.6]; *p*=0.0001), contusions (1.2 [95% CI: 0.4 to 3.2] per 1,000 training-hrs; RR: 7.3 [95% CI: 2.6 to 20.6]; *p*<0.0001) and concussions (0.3 [95% CI: 0.0 to 2.1] per 1,000 training-hrs; RR: 29.0 [95% CI: 4.0 to 212.8]; *p*<0.0001) (see Table 9). Although sprains and strains resulted in more time-loss training injuries (2.6 [95% CI: 1.2 to 5.9] per 1,000 training-hrs) than dislocations, fractures (1.2 [95% CI: 0.4 to 2.3] per 1,000 training-hrs; RR: 1.5 [95% CI: 0.4 to 5.3]; *p*=0.5271) and concussion (0.3 [95% CI: 0.0 to 2.1] per 1,000 training-hrs; RR: 6.0 [95% CI: 0.7 to 49.8]; *p*=0.0588) this was not significant.

Table 8: Player position and injury site of training injuries for an amateur women's rugby union team in New Zealand for total and time-loss-training injuries over two consecutive years. Data reported as number of injuries, rates per 1,000 training-hrs with 95% confidence intervals, injury burden total days lost, mean days lost per injury with standard deviation and rates per 1,000 training hours with 95% confidence intervals.

	Total Injuries					**Time-Loss Injuries**				
	Injury Incidence		**Injury Burden**			**Injury Incidence**		**Injury Burden**		
	n=	**Rate Mean (95% CI)**	**Total**	**Days Mean ±SD**	**Rate Mean (95% CI)**	**n=**	**Rate Mean (95% CI)**	**Total**	**Days Mean ±SD**	**Rate Mean (95% CI)**
Player position										
Forwards	25	7.5 (5.1-11.1)	224	8.6 ±12.9	131.0 (115.0-149.4)	8	2.4 (1.2-4.8)	190	21.1 ±16.1	111.1 (96.4-128.1)
Backs	13	3.9 (2.3-6.7)	69	5.0 ±6.0	40.4 (31.9-51.1)	4	1.2 (0.6-3.6)	43	14.3 ±5.5	25.2 (18.7-33.9)
Total	**38**	**11.4 (8.3-15.6)**	**293**	**7.3 ±11.0**	**171.4 (152.9-192.2)**	**12**	**3.6 (2.0-6.3)**	**233**	**19.4 ±14.3**	**136.3 (119.9-155.0)**
Injury site										
Head/Neck	**5[e]**	**1.5 (0.6-3.6)**	**53**	**10.6 ±11.9**	**31.0 (23.7-40.6)**	**2**	**0.6 (0.1-2.4)**	**44**	**22.0 ±11.3**	**25.7 (19.2-34.6)**
Head	1	0.3 (0.0-2.1)	30	30.0 -	17.5 (12.3-25.1)	1	0.3 (0.0-2.1)	30	30.0 -	17.5 (12.3-25.1)
Neck	4	1.2 (0.4-3.2)	23	5.8 ±5.7	13.5 (8.9-20.2)	1	0.3 (0.0-2.1)	14	14.0 -	8.2 (4.9-13.8)
Upper limb	**8[e]**	**2.4 (1.2-4.8)**	**61**	**6.1 ±6.7**	**35.7 (27.8-45.9)**	**3**	**0.9 (0.3-2.8)**	**52**	**17.3 ±6.4**	**30.4 (23.2-39.9)**
Shoulder	3	0.9 (0.3-2.8)	26	4.7 ±0.6	15.2 (10.4-22.3)	1	0.3 (0.0-2.1)	21	21.0 -	12.3 (8.0-18.8)
Elbow	1	0.3 (0.0-2.1)	2	2.0 -	1.2 (1.6-7.8)	0	0.0 -	0	0.0 -	0.0 -
Finger	4	1.2 (0.4-3.2)	33	8.3 ±9.5	19.3 (13.7-27.2)	2	0.6 (0.1-2.4)	31	15.5 ±7.8	18.1 (12.8-25.8)
Lower limb	**28[cdf]**	**8.4 (5.8-12.1)**	**170**	**7.4 ±12.5**	**99.4 (85.6-115.6)**	**7[f]**	**2.1 (1.0-4.4)**	**128**	**21.3 ±19.4**	**74.9 (63.0-89.0)**
Hamstring	2	0.6 (0.1-2.4)	6	3.0 ±2.8	3.5 (1.6-7.8)	0	0.0 -	0	0.0 -	0.0 -
Knee	3	0.9 (0.3-2.8)	36	12.0 ±9.2	21.1 (15.2-29.2)	2	0.6 (0.1-2.4)	34	17.0 ±4.2	19.9 (14.2-27.8)
Patella	5	1.5 (0.6-3.6)	29	7.3 ±6.7	17.0 (11.8-24.4)	2	0.6 (0.1-2.4)	25	12.5 ±4.9	14.6 (9.9-21.6)
Lower Leg	4	1.2 (0.4-3.2)	11	3.7 ±4.6	6.4 (3.6-11.6)	1	0.3 (0.0-2.1)	9	9.0 -	5.3 (2.7-10.1)
Ankle	8	2.4 (1.2-4.8)	68	12.0 ±23.6	39.8 (31.4-50.5)	1	0.3 (0.0-2.1)	60	60.0 -	35.1 (27.3-45.2)
Foot	6	1.8 (0.8-4.0)	20	3.8 ±5.0	11.7 (7.5-18.1)	1	0.3 (0.0-2.1)	14	14.0 -	8.2 (4.9-13.8)
Chest/Back	**1[e]**	**0.3 (0.0-2.1)**	**9**	**9.0 -**	**5.3 (2.7-10.1)**	**1[e]**	**0.3 (0.0-2.1)**	**9**	**9.0 -**	**5.3 (2.7-10.1)**
Pelvis	1	0.3 (0.0-2.1)	9	9.0 -	5.3 (2.7-10.1)	1	0.3 (0.0-2.1)	9	9.0 -	5.3 (2.7-10.1)

CI = Confidence Intervals; SD = Standard Deviation; Significant difference ($p<0.05$) than (a) = Sprains/Strains; (b) = Contusions; (c) = dislocation; (d) = fracture (e) = wound; (f) = concussion.

Table 9: Injury type, injury cause, and training period of an amateur women's rugby union team in New Zealand for total and time-loss-training injuries over two consecutive years. Data reported as number of injuries, rates per 1,000 training-hrs with 95% confidence intervals, injury burden total days lost, and mean days lost per injury with standard deviation and rates per 1,000 training hours with 95% confidence intervals.

	Total injuries					**Time-Loss training injuries**				
	Injury Incidence		**Injury Burden**			**Injury Incidence**		**Injury Burden**		
	n=	**Rate Mean (95% CI)**	**n=**	**Days Mean ±SD**	**Rate Mean (95% CI)**	**n=**	**Rate Mean (95% CI)**	**n=**	**Days Mean ±SD**	**Rate Mean (95% CI)**
Injury type										
Sprains/Strains	29	8.7 (6.0-12.5)[bcdef]	84	3.6 ±3.3	49.1 (39.7-60.9)	6	1.8 (0.8-4.0)	32	10.7 ±2.9	18.7 (13.2-26.5)
Contusions	4	1.2 (0.4-3.2)[a]	22	7.7 ±13.2	12.9 (8.5-19.5)	1	0.3 (0.0-2.1)	20	20.0 -	11.7 (7.5-18.1)
Dislocation	6	1.8 (0.8-4.0)[a]	29	4.3 ±4.0	17.0 (11.8-24.4)	4	1.2 (0.4-3.2)	25	12.5 ±5.0	14.6 (9.9-21.6)
Fracture	4	1.2 (0.4-3.2)[a]	126	31.5 ±20.2	73.7 (61.9-87.8)	4	1.2 (0.4-3.2)	126	31.5 ±20.2	73.7 (61.9-87.8)
Wound	1	0.3 (0.0-2.1)[a]	2	2	1.2 (0.3-4.7)	0	0.0 -	0	0.0 -	0.0 -
Concussion	1	0.3 (0.0-2.1)[a]	30	30.0 -	17.5 (12.3-25.1)	1	0.3 (0.0-2.1)	30	30.0 -	17.5 (12.3-25.1)
Injury cause										
Tackle related	10	3.0 (1.6-5.6)	156	15.6 ±20.6	91.3 (78.0-106.8)	3	0.9 (0.3-2.8)	111	37.0 ±20.4	64.9 (53.9-78.2)
Ball Carrier	5	1.5 (0.6-3.6)	40	8.0 ±11.2	23.4 (17.2-31.9)	1	0.3 (0.0-2.1)	30	30.0 -	17.5 (12.3-25.1)
Tackler	5	1.5 (0.6-3.6)	116	23.2 ±26.2	67.9 (56.6-81.4)	2	0.6 (0.1-2.4)	81	40.5 ±27.6	47.4 (38.1-58.9)
Collision	6	1.8 (0.8-4.0)	37	6.2 ±7.6	21.6 (15.7-29.9)	5	1.5 (0.6-3.6)	68	13.6 ±5.9	39.8 (31.4-50.5)
Fall	4	1.2 (0.4-3.2)	13	3.3 ±1.7	7.6 (4.4-13.1)	0	-	0	0.0 -	0.0 -
Slip	4	1.2 (0.4-3.2)	10	2.5 ±1.3	5.8 (3.1-10.9)	0	-	0	0.0 -	0.0 -
Twist	9	2.7 (1.4-5.2)	44	4.9 ±6.1	25.7 (19.2-34.6)	3	0.9 (0.3-2.8)	39	13.0 ±3.6	22.8 (16.7-31.2)
Overexertion	9	2.7 (1.4-5.2)	33	3.7 ±4.5	19.3 (13.7-27.2)	1	0.3 (0.0-2.1)	15	15.0 -	8.8 (5.3-14.6)
Injury period										
1st half	19	5.7 (3.6-8.9)	123	6.9 ±8.1	72.0 (60.3-85.9)	5	3.0 (1.2-7.2)	85	17.0 ±8.5	49.7 (40.2-61.5)
2nd half	23	6.9 (4.6-10.4)	170	7.7 ±13.2	99.4 (85.6-115.6)	7	4.2 (2.0-8.8)	148	21.1 ±17.8	86.6 (73.7-101.7)

CI = Confidence Intervals; SD = Standard Deviation; Significant difference (p<0.05) than (a) = Sprains/Strains; (b) = Contusions; (c) = dislocation; (d) = fracture (e) = wound; (f) = concussion.

The tackle was the most commonly reported injury cause for total (3.0 [95% CI: 1.6 to 5.6] per 1,000 training-hrs.) injuries, but collisions (1.5 [95% CI: 0.6 to 3.6] per 1,000 training-hrs.) with the ground and other people not being tackled were the most common cause for time-loss injuries. There were more total (6.9 [95% CI: 4.6 to 10.4] vs. 5.7 [95% CI: 3.6 to 8.9] per 1,000 training-hrs; RR: 1.2 [95% CI: 0.7 to 2.3]; p=0.5164) and time-loss (4.2 [95% CI: 2.0 to 8.8] vs. 3.0 [95% CI: 1.2 to 7.2] per 1,000 training-hrs; RR: 1.4 [95% CI: 0.4 to 4.4]; p=0.5637) training injuries recorded in the latter stages of training compared with the early parts of training, but this was not significant.

Discussion

This prospective observational study documented training injury incidence for an amateur women's rugby team over two consecutive domestic competition seasons. The principal findings of this study revealed: (1) A total injury incidence of 11.4 (95% CI: 8.3 to 15.6) per 1,000 training-hrs and a total injury burden of 171.4 (95% CI:152.9 to 192.2) per 1,000 training-hrs; (2) A time-loss injury incidence of 3.6 (95% CI: 2.0 to 6.3) per 1,000 training-hrs and a time-loss injury burden of 136.3 (95% CI: 119.9 to 155.0) per 1,000 training-hrs; (3) The lower limb injury recorded the highest total injury incidence and injury burden with the ankle sustaining the greatest proportion of injuries and the highest time-loss injury burden; (4) The tackle was associated with a higher total and time-loss injury incidence and injury-burden than any other training event; and (5) Sprains and strains recorded the highest total injury incidence and fractures recorded the highest time-loss injury burden.

The time-loss injury incidence (3.6 per 1,000 training-hrs.) over the duration of the study was similar to the 2006 RWC(W) (3.0 per 1,000 training-hrs.),[285] but slightly higher than the National[46] level (1.2 per 1,000 practice-hrs). Similar to the different participation levels in male rugby union, the training injury incidence may be reflective of the level of playing standard.[261] This can be seen in the second year of the study where the overall injury incidence was 14.7 per 1,000 training-hrs and the significant difference (p=0.0008) between expected and actual injuries recorded. This may be due to having new players join the team in the second year of the study and some of them had none to minimal previous rugby union experience. In addition, there were several players who had recently arrived from overseas for the New Zealand experience of women's rugby union and were not conversant with the training methodologies being implemented. As a result, many training injuries occurred in pre-season. This may have been unique to this cohort or there may be other factors involved (i.e., coaching styles, fitness levels etc.) and further research is warranted to explore the influencing factors associated with training injuries.

Forwards recorded a higher injury incidence and injury burden for both the all-inclusive (7.5 vs. 3.9 per 1,000 training-hrs; 131.0 vs. 40.4 per 1,000 training-hrs.) and time-loss (2.4 vs. 1.2 per 1,000 training-hrs; 111.1 vs. 25.2 per 1,000 training-hrs.) injury definitions, when compared with Backs. As previously reported,[188] no studies reporting on women's rugby union training injuries provided player position information, therefore, comparisons were unable to be completed. The finding that Forwards recorded a higher injury incidence than Backs is similar to male professional participants (Forwards: 2.1 vs. Backs: 1.8 per 1,000 training-hrs.)[32] but conflicts with the male Rugby World Cup (RWC) (Forwards: 7.2 vs. Backs: 9.1 per 1,000 training-hrs.)[33] level of participation. Differences in player position injury incidence at professional and RWC participation levels may have been reflective of that study cohort or this may be due to differing demands placed upon players at different participation levels, such as eligibility for selection or limited playing group and pressure to play on. This may be similar at the elite level of women's rugby union; therefore, further training injury research is warranted to establish the epidemiology of women's rugby union training injuries.

The lower limb (consisting of the knee, lower leg, ankle, foot, and toes) was the most common injury location and had the highest injury burden for both the all-encompassing (8.4 per 1,000 training-hrs; 99.4 per 1,000 training-hrs.) and time-loss (2.1 per 1,000 training-hrs; 74.9 per 1,000 training-hrs.) injury definitions. However, when viewed by injury site, the ankle recorded the most all-encompassing (2.4 per 1,000 training-hrs; 39.8 per 1,000 training-hrs.) training injuries and injury burden while the knee and patella recorded the most time-loss (0.6 per 1,000 training-hrs.) training injuries and the ankle recorded the highest time-loss injury burden (35.1 per 1,000 training-hrs.). This was similar to some,[46, 302] but not all,[57, 285] studies reporting on women's rugby union training injuries. The head and neck were the most common injury sites at the collegiate and RWC(W) participation levels.[57, 285] In a recent study on injury insurance claims over 12 yrs., female players had higher claim rates for injuries to the knee and ankle when compared to male players.[264] In addition, females had a similar injury rate in the 21 to 30 yr. age group compared with males, but a substantially higher injury rate in the 31 to 40 yr. age group.[264] Unfortunately, these data were not able to differentiate match from training injuries, therefore more research is warranted to identify if the training injury incidence in these injury locations is higher in the similar age groups and participation levels.

When combined, the tackle accounted for nearly a quarter (23.8%) of the total and time-loss (25.0%) injuries. The tackler accounted for more time-loss (16.7% vs. 8.3%) injures than the ball-carrier and this may be indicative of their lack of skill when tackling or the effects of fatigue. This was less than a previous study by Kerr *at al.*,[175] where the tackle accounted for nearly half (40.5%) of the training injuries, however, the ball carrier (22.1%) accounted for a higher percentage of injuries than the tackler (18.3%). Although the tackle recorded the highest number of training injuries, when separated to ball carrier and tackler this was less than collisions. The one concussion that occurred during training also occurred in the preseason during a tackling drill.

It has previously been reported[122] that players with lower momentum going in to the tackle are more likely to be injured. This premise was further supported in a subsequent study that identified[21] that women's rugby union posed the greatest injury risk given the number of possible mechanisms of injury such as the tackle, and the lack of protective equipment inherent in the sport.[306] Players technical ability and proficiency, action within the tackle,[42] and momentum in both attack and defence in the tackle[10] are reportedly major risk factors for injuries occurring. This may be the case with this women's rugby union competition where there is only one level of participation and players of different ability compete against each other. As women's participation is a new growth area in rugby union,[188] the experience and physical and anthropometric characteristics of players are likely to be less, when compared with their male counterparts, yet the women participate under the same rules and regulations as males. As the mean playing experience in this cohort was 4.3 yrs., they could be considered similar to younger players and not have the experience and physiological conditioning of similarly aged male rugby union participants. In addition, the previously reported[268] differences in agility, aerobic performance, momentum, and fatigue index may also impact on the incidence of injuries that occur in women's rugby union. As the previous research[268] on the anthropometric and physical performance of New Zealand women participants is dated, further research is warranted to explore these areas and any possible influences this may have on the incidence of injuries in women's rugby union.

More than half of total (54.8%) and time-loss (58.3%) training injuries occurred in the later stages of trainings. Previous studies that have reported training injuries in women's rugby union have not reported the training period so no comparisons could be undertaken. Although all players were required to conduct a warm-up prior to commencing training, some players would arrive late due to work or family commitments and either do a jog around the training area or run straight into the training activity. The identification of the injury period will assist with the development of injury prevention protocols for women rugby union players in relationship to warm-ups, types of training activities that place them at risk and any modifications that are required to reduce this injury risk, while still conditioning the players to match type activities.

The majority (71.2%) of injuries that occurred during training resulted in minimal training sessions missed. This was similar to a study at the high school level of participation where minor (<10 days' time loss) injuries accounted for 55.9% of all injuries. However, compared to collegiate (major: >7 days' time loss; 51%) and International (severe: >2 weeks' time loss; 44%) participation levels, the majority of injuries recorded were of the time-loss classification. The differences in the percentage of injuries classified for time-loss are in the methodological approaches utilised by these different studies, and future studies should utilise similar methodological approaches to enable cross-study comparisons.

Limitations

This study was conducted with an amateur women's rugby union team participating in the lower-level women's domestic rugby union competition. Although the competition was divided into two rounds, the first round saw all teams participate against each other before the second round, when the group was divided into two divisions. The current cohort of players participated in the division two competition for the second round of each season, therefore the findings should be interpreted with caution, as they may not reflect the higher participation levels. The time-loss finding of 3.6 per 1,000 training hours (n=12) for the current study may be unique to this cohort and interpretation of these results should be undertaken with caution. The finding that there were more injuries in 2019 when compared with 2018, may be related to a combination of factors. These are: (1) the number of new players that were enrolled with the team in 2019 with no, or limited, playing experience; and (2) the number of Forwards when compared to Backs (2018: Forwards = 18; Backs = 17; 2019: Forwards = 23; Backs = 11; Total Forwards = 41; Backs = 28). As Forwards are more likely to be involved in contact related activities this may have influenced the findings reported in this study. Further research is recommended, and the inclusion of player experience and player role should be recorded to enable further analysis. This study did not record female-specific aspects such as use of oral contraceptives and the phase of the menstrual cycle when the injuries occurred.[78, 234] It has been identified[188] that this aspect may be important for future research and should be considered in any further women's rugby union injury studies.

Conclusions

The paucity of studies on women's rugby-15s training injuries was the catalyst for this study to report the incidence, site, type, and timing of injuries over two consecutive competition seasons of an amateur women's team in New Zealand. The findings indicate that training injuries occur most often to the lower limb and during the latter part of training sessions. These injuries are mostly minor in nature, resulting in minimal time-loss away from training. The time-loss training injury incidence in amateur women's rugby union in New Zealand was higher than that reported for national and international injury incidences.

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STATEMENT OF CONTRIBUTION
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Chapter 5: Incidence of match injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons

This chapter comprises the following paper published in *Advances in Orthopedics and Sports Medicine*

Reference

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Incidence of match injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons. *Advances in Orthopedics and Sports Medicine,* AOASM-129

Overview

Background: Rugby Union is played in over 200 countries with over 8.5 million registered players worldwide. Despite increased popularity of the game for women, there is relatively little evidence for incidence, causes or severity of injuries that occur during match participation.

Purpose: To determine whether amateur women's rugby union teams in New Zealand need injury prevention support, by providing evidence as to the incidence, causes and severity of injuries that occur during match participation.

Study design: Descriptive epidemiological observational study.

Methods: Epidemiology analysis to describe the incidence of match injuries in an amateur women's rugby union team in New Zealand, over two consecutive seasons. Injury burden was calculated for all injuries by: injury region, reported as frequency of injuries by region; number of days lost; and mean number of days lost, with standard deviation.

Results: Over the study, 138 injuries were recorded resulting in an injury incidence of 247.0 per 1,000 match-hrs. A total of 57 resulted in a time-loss injury incidence of 102.0 per 1,000 match-hrs. The hooker recorded a significantly lower mean (4.1 ±2.8 days) injury burden than the blind-side flanker ($t_{(6)}$=-2.8; p=0.0314), centre ($t_{(6)}$=-2.8; p=0.0313) and fullback ($t_{(6)}$=-2.7; p=0.0351) for total injuries.

Discussion: The principal findings of this study were: (1) total injury incidence was 247.0 per 1,000 match-hrs; (2) time-lost from rugby due to injuries was 102.0 per 1,000 match-hrs; (3) the lower limb sustained the highest injury incidence with the knee having the greatest proportion of these injuries; (4) the tackle recorded the highest injury rate, and being tackled was associated with a notably higher injury incidence than any other match event; (5) sprains and strains recorded the highest injury incidence; and (6) the lower limb body region recorded the most days lost and had the highest mean days lost per injury.

Key terms: Rugby; Women; Injuries; injury-burden.

Introduction

Rugby Union (more commonly known as rugby) is a sport played in over 200 countries with over 8.5 million registered players worldwide.[332] Played over two 40 minute halves, interspersed with a 10-minute rest interval,[80, 89, 243] rugby is a full contact collision sport characterised by frequent bouts of both high-intensity (e.g. running, tackling, rucks, mauls, passing and sprinting) and low intensity (e.g. jogging and walking) intermittent activities throughout match activities.[58, 80] As rugby is a physical sport, players are exposed to repeated collisions, and this integral part of the game[36] places an inherent risk of injuries occurring.[322]

Female involvement in rugby has increased in popularity with over 2 million women participating under the same rules as their male counterparts at the community and elite levels of participation.[104] Although women participate in match activities under the same rules as males, females reportedly have higher injury risks,[18] even though they have lower physiological indices (e.g. reduced speed and less agility, lower muscular power, lower estimated maximal aerobic power) compared with males.[196] Interestingly, injury patterns differ between males and females in other sports such as basketball,[72] football,[316] handball,[206] and rugby league.[193]

Despite increased popularity of the game for women, there is relatively little recorded evidence of incidence, causes or severity of injuries that occur during match participation. In a recent systematic review,[188] there were only seven papers available since 1990 reporting on women's rugby match injuries,[46, 57, 79, 175, 257, 285, 302] compared with more than 113 studies[36, 322, 332] reporting on men's rugby. It was reported[188] that the incidence of injuries in women's rugby varied from 3.6 (95% CI: 2.5 to 5.3) per 1,000 playing (match and training) hr.[79] to 37.5 (95% CI: 28.0 to 50.2) per 1,000 match-hr.,[285] which was lower than professional men's rugby (81 [95% CI: 63 to 105] per 1,000 match-hr.),[322] but similar to children and adolescent rugby pooled injury incidence (26.7 [95% CI: 13.2 to 54.1] per 1,000 match-hr.).[94] Importantly, in reporting these studies it was identified that some injury definitions utilised a missed match or time-loss definition, that is only reporting injuries that resulted in a match being missed, whereas other studies reported all-encompassing, or medical treatment injuries that occurred as a result of match participation.[188] As a result, these variations in injury methodologies limit inter-study comparisons.

Recently, there has been a call for research efforts to be directed towards development of an evidenced based framework towards an understanding of women's physiological, training, injury and illness surveillance data.[65, 239] In order to address this call, the aim of this study was to report the incidence of amateur women's rugby match injuries, over two consecutive competition seasons, and to compare these with published studies on women's contact and/or collision sports.

Objectives

To record and report the incidence, causes and severity of injuries that occur during match participation in women amateur rugby union players.

Methods

A prospective cohort epidemiological study was undertaken to was undertaken to document incidence of match injuries occurring in an amateur women's rugby team over the 2018 and 2019 domestic seasons. A total of 69 (age: 26.5 ±7.4 years [range: 17.6 to 48.5 years]; Height: 1.67 m ±0.08m [range 1.50-1.80 m]; mass 87.1 kg ±18.9 [range 50-127 kgs] years playing experience 4.3 ±4.2 years [range 0-18 years]) participants from the same team over two consecutive years participating in a domestic level competition. A total of 34 players participated in the first season and 35 players competed in the second season. A total of 22 players participated in both competition seasons. Player medical history, including previous concussion history were collected in the pre-season period before the player undertook any training activity.[187] The players were also monitored[201] for changes in stress and recovery using the multidimensional Recovery-Stress Questionnaire for Athletes (RESTQ-Sport)[172] 52-item questionnaire.

All players were considered amateur, as they received no remuneration for participating in rugby union activities and derived their main source of income from other employment activities. Players competed in a single level competition where all teams (the number varied each year) played each other once before the top five were identified for a second-round top five and bottom six competition format. There were a total of 28 matches played under the rules and regulations of the New Zealand Rugby Football Union, with matches comprising of two 40-minute halves, with a resulting match exposure of 558.6 match exposure hrs.

Players were categorised according to their (1) playing group and (2) positional group.[45] These two groups were: (1a) Forwards (loose-head prop, hooker, tight-head prop, left lock, right lock, blind-side flanker, open-side flanker, and number eight) and (1b) Backs (halfback, fly-half, left wing, inside centre, outside centre, right wing, and full back); and (2a) Front-Row Forwards (loose-head prop, tight-head prop; left lock, right lock); (2b) Back-Row Forwards (hooker; blind-side flanker, open-side flanker, number eight); (2c) In-Side Backs (halfback; fly-half, inside centre, outside centre) and (2d) Out-Side Backs (left wing, right wing, full back). The hooker was included in the Back Row Forward's due to their roving style of play.[74]

Injury assessment and definition

The injury definition utilised for this study was "*Any physical complaint, which is caused by a transfer of energy which exceeds the ability of the body's ability to maintain its* *structural and/or functional integrity, that is sustained by a player during a rugby match, irrespective of the need for medical attention or time-loss from rugby activities.*"[98]

Injury rates were determined using previously described methods.[149, 182] These were expressed as the number of injuries sustained per 1000 match hours. Over the competition, all match injuries were recorded, irrespective of severity, to enable further analysis for total and time-loss analysis.

The team medic (DK) was a registered comprehensive nurse with tertiary sports medicine qualifications and accredited in injury prevention, assessment, and management. Injury data were collected from all match activities the team participated in. All injuries that occurred during match activities that were attended to by the team medic were recorded on a standardized injury reporting form regardless of severity,[181] recording details of each injury, including date of onset of injury, date of return to training, injury location, injury type, injury cause, player position,[98] player role (forward, back) and Orchard Sports Injury Code (v10.1).[252] If more than one injury occurred to an injury site, these were recorded individually as injury type. As a result, there were more injury types than total injuries recorded. Severity of injuries were recorded as mean (days-absence) and also within grouped severity time-loss values (slight: 0-1 days; minimal: 2-3 days, mild: 4-7 days, moderate: 8-28 days and severe: >28 days).[98]

Both total and time-loss injuries were recorded and reported throughout the study. This was undertaken to provide an accurate picture of the injury incidence in women's rugby union.[146] Time-loss injuries were classified as those injuries that resulted in the player being unable to take a full part in future rugby training or match activities.[98] In terms of this study, this was any injury that was classified as mild, moderate or severe. Injuries classified as slight or minimal were not classified as time-loss as no matches were missed and these injuries did not meet the time-loss definition.[98]

Concussion assessment and definition

All players completed the King-Devick (K-D) baseline test (Mayo Clinic endorsed) during the preseason training period[197] using standardized protocols.[185, 191, 274] The K-D test is a rapid number recognition naming task that takes < 2 minutes to administer.[73] The participants read aloud a sequence of single digit numbers from a screen left to right that includes one demonstration card and three visually distinct test cards that increase in difficulty.[117] Utilised across a wide variety of contact and collisions sports,[116, 117, 119, 185] K-D has a high sensitivity (0.86; 95% CI: 0.79 to 0.92), specificity (0.90; 95% CI: 0.85 to 0.93) and an Inter Class Correlation (ICC) of 0.91 (95% CI: 0.85 to 0.97).[118, 334]

All players were tested during pre-season on a tablet (iPad; Apple Inc., Cupertino, CA) according to the developer's recommendations (v4.2.2; King-Devick technologies Inc.). All baseline testing was completed at training to mimic the sideline playing field environments. Players were asked to read card numbers from left to right as quickly as they could without making any errors using standardized instructions. Time was kept for each test card, and the entire test K-D summary score was based on the cumulative time taken to read all three test cards.[242] The number of errors made in reading test cards was recorded. The best time (fastest) of two trials 5-minutes apart without errors became the established baseline K-D test time.[116]

During matches, the lead researcher (and team medic), observed players for any signs of direct contact to the head, or being slow to rise from a tackle or collision, or being unsteady on their feet following a collision. If this occurred, players were assessed on-field. If any signs of delayed answering, incorrect answers to questions, or if the player appeared to be impaired in any way, the player was removed from match activity and rested on the sideline. Players who reported any sign(s) of a concussion, who were suspected to have received a concussion, or who were removed from match participation were initially assessed with the sideline K-D test after a 15-minute rest period; not allowed to return to play on the same day; and, referred for further medical assessment. The test was administered once using the same instructions, and time and errors were recorded and compared to the participant's baseline. Worsening time and/or errors identified on the sideline or post-match K-D have been associated with concussive injury.[116, 117, 119] The K-D test performance has been shown to be unaffected in various noise levels and testing environments.[292]

No player who had been identified with delayed (worsening) post-match K-D times were allowed to return to training or match activities without a full medical clearance. Players with a loss of consciousness were treated for a cervical spine injury and managed accordingly. All suspected concussive injuries were evaluated by the player’s own health professional. All players that were identified with a delay (worsening) of the K-D test from their baseline were formally assessed by their health professional. No player was allowed to return to full match activities until they were medically cleared and, had returned to their baseline K-D score.

Concussions were classified as witnessed (a concussive injury that met the definition of a concussion,[224] that was identified during match activities resulting in removal from match activities and had >3 s for pre to post-match K-D, and later confirmed by a health professional's clinical assessment) or unwitnessed (changes >3 s for pre to post-match K-D with associated changes, and later confirmed by a physician's clinical assessment). The 3 s threshold for changes in post-match K-D is identical to studies reporting K-D test use.[177, 178] The definition of a concussion utilised for this study was "*any disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms and often does not involve loss of consciousness. Concussion should be suspected in the presence of any one or more of the following: (a) Symptoms (such as headache), or (b) Physical signs (such as unsteadiness), or (c) Impaired brain function (e.g. confusion) or (d) Abnormal behaviour.*"[224] An 'unwitnessed' concussion was defined for the purpose of this study as "*any disturbance in brain function caused by a direct, or indirect force, to the head that does not result in any immediate observable symptoms, physical signs, impaired brain function or abnormal behaviour but had a delay in the post-match K-D score of >3 s and associated changes in the post-match SCAT5.*"[185]

Statistical analysis

All data collected were entered into a Microsoft Excel spreadsheet and analysed with Statistical Package for Social Sciences for Windows (SPSS; V25.0.0). Match exposure was calculated based on 15 players being exposed for 80 minutes, positional groups exposure was based on the number of players in the group (i.e., Front-Row Forwards, Back-Row Forwards, Inside Backs) were exposed for 80 minutes. This was similar for Forwards and Backs where the exposure was based on either eight or seven players playing for 80 minutes, respectively. Match injury incidence was calculated as the number of injuries per 1,000 match-hrs, ((Σ injuries/Σ exposure hrs) x1000) with 95% confidence intervals (CI's). A one-sample chi-squared (χ^2) test was used to determine whether the observed injury frequency was significantly different from the expected injury frequency by competition year and for total injuries recorded. Cohen's effect size (*d*) were utilised to calculate practically meaningful differences between playing groups (Front-Row Forwards, Back-Row Forwards; Inside Backs and Outside Backs) and injury burden days lost. Effect sizes of <0.19, 0.20-0.60, 0.61-1.20 and >1.20 were considered trivial, small, moderate, and large, respectively.[155] To compare between injury rates per year, total and time-loss injuries recorded, risk ratios (RR's) were used. The RRs were assumed to be significant at $p<0.05$. A two-sample *t*-test was used to determine the differences in the injury burden by competition year.

Results

Table 10: Player age, height, body mass and years playing experience for Backs, Forwards, and total players over the 2018- and 2019-women's rugby union competitions in New Zealand. Data reported by number of players and mean with standard deviation.

		2018		2019		Total
	n=	Mean ±SD	n=	Mean ±SD	n=	Mean ±SD
Age						
Forwards	18	25.6 ±6.9[d]	23	31.0 ±8.3[c]	41	28.6 ±8.1[b]
Backs	17	22.8 ±4.7	11	24.4 ±5.5	28	23.4 ±4.9[a]
Total	35	24.2 ±6.0[d]	34	28.9 ±8.0[c]	69	26.5 ±7.4
Height						
Forwards	18	1.69 ±0.79	23	1.64 ±0.57	41	1.66 ±0.71
Backs	17	1.64 ±0.81	11	1.64 ±0.66	28	1.64 ±0.74
Total	35	1.67 ±0.82	34	1.64 ±0.59	69	1.65 ±0.72
Weight						
Forwards	18	95.3 ±20.7[b]	23	90.3 ±11.5[b]	41	92.5 ±15.2[b]
Backs	17	78.3 ±12.0[a]	11	77.6 ±9.2[a]	28	78.0 ±10.8[a]
Total	35	87.1 ±18.9	34	86.2 ±12.3	69	86.6 ±15.9
Playing Experience						
Forwards	18	4.4 ±4.2	23	4.3 ±4.3	41	4.3 ±4.2
Backs	17	3.0 ±2.4	11	6.2 ±5.8	28	4.3 ±4.3
Total	35	3.9 ±3.4	34	4.9 ±4.8	69	4.3 ±4.2

SD = Standard Deviation; Significant difference (p<0.05) than (a) = Forwards; (b) = Backs; (c) = 2018; (d) = 2019.

Injury incidence, and age

Over the study, the cohort of players were significantly older in 2019 than in 2018 (28.9 ±8.0 yr. vs. 24.2 ±6.0; $t_{(17)}$=-2.4; p=0.0289) (see Table 10). Forwards were older (28.6 ±8.1 yr. vs. 23.4 ±4.9 yr.; $t_{(27)}$=4.4; p=0.0001) and heavier (92.5 ±15.2 kg vs. 78.0 ±10.8 kg; $t_{(27)}$=4.1; p=0.0003) than Backs. Backs did not record more playing experience in 2019 (6.2 ±5.8 yr. vs. 3.0 ±2.4; $t_{(10)}$=-1.3l p=0.2280) compared with 2018.

There were significantly more total injuries in 2019 (184.8 [95% CI: 143.2 to 238.6]) per 1,000 match-hrs.) than 2018 (330.0 [95% CI: 264.7 to 411.4] per 1,000 match-hrs.; RR: 1.8 [95% CI: 1.3 to 2.4]; p=0.0006) (see Table 11). As a result, the 138 injuries recorded over the study resulted in an injury incidence of 247.0 (95% CI: 60.6 to 291.9) per 1,000 match-hrs.

Player positions

The halfback recorded significantly fewer injuries (107.4 [95% CI: 40.3-286.2] per 1,000 match hrs.) than the tight-head prop (RR: 3.3 [95% CI: 1.1 to 9.9]; p=0.0290), blind-side flanker (RR: 3.3 [95% CI: 1.1 to 9.9]; p=0.0290) and right-wing (RR: 3.0 [95% CI: 1.0 to 9.3]; p=0.0455) (see Table 12). The hooker recorded a significantly lower mean (4.1 ±2.8 days) injury burden than the blind-side flanker ($t_{(6)}$=-2.8; p=0.0314; d=0.61), centre ($t_{(6)}$=-2.8; p=0.0313; d=1.30) and fullback ($t_{(6)}$=-2.7; p=0.0351; d=1.49) for total injuries. As a result, front-row forwards (12.8±19.7 days) recorded a significantly lower mean injury burden than outside backs ($t_{(29)}$=-2.3; p=0.0312; d=0.41).

Table 11: Total and time-loss injuries, injury rate, injuries per match and match minutes per injury in an amateur domestic women's rugby union team in New Zealand over two consecutive years for total and time-loss injuries. Data reported as number of injuries, rates per 1,000 match hours with 95% confidence intervals.

	Total Match Injuries			**Time-loss Injuries**		
	2018	**2019**	**Total**	**2018**	**2019**	**Total**
Injuries Observed, n	59[b]	79[a]	138	28	29	57
Injuries Expected, n	78.9	59.1	138	32.6	24.4	57
Injury rates per 1,000 match hours, m (95% CI)	184.8 (143.2-238.6)	330.0 (264.7-411.4)	247.0 (209.1-291.9)	87.7 (60.6-127.0)	121.1 (84.2-174.3)	102.0 (78.7-132.3)
No. matches played, n	16	12	28	16	12	28
Exposure hrs, n	319.2	239.4	558.6	319.2	239.4	558.6
Hrs per injury, m (95% CI)	5.4 (4.2-7.0)	3.0 (2.4-3.8)	4.0 (3.4-4.8)	11.4 (7.9-16.5)	8.3 (5.7-11.9)	9.8 (7.6-12.7)
Total No. Injuries per match, m (95% CI)	3.7 (2.9-4.8)	6.6 (5.3-8.2)	4.9 (4.2-5.8)	1.8 (1.2-2.5)	2.4 (1.7-3.5)	2.0 (1.6-2.6)
Player appearances per injury, m (95%CI)	4.1 (3.2-5.3)	2.3 (1.8-2.8)	3.0 (2.6-3.6)	8.6 (5.9-12.4)	6.2 (4.3-8.9)	7.4 (5.7-9.6)
Match minutes played per injury, m (95%CI)	21.7 (16.8-28.0)	12.2 (9.7-15.2)	16.2 (13.7-19.2)	45.7 (31.6-66.2)	33.1 (23.0-47.6)	39.3 (30.3-5.09)

n = number; m = median; CI = Confidence Interval; Significant difference (p<0.05) than (a) = 2018; (b) = 2019.

Table 12: Player position, player group and player role for injuries that occurred in an amateur women's rugby union team in New Zealand for total injuries and time-loss injuries over two consecutive years by injuries recorded, rates per 1,000 match hours with 95% confidence intervals, number of days lost, mean number of days lost with standard deviation and rates per 1,000 match hours with 95% confidence intervals.

	Total Injuries					Time-Loss Injuries				
	Injury Incidence		Injury Burden			Injury Incidence		Injury Burden		
	n=	Rate Mean (95% CI)	Total	Days Mean ±SD	Rate Mean (95% CI)	n=	Rate Mean (95% CI)	Total	Days Mean ±SD	Rate Mean (95% CI)
Player position										
1. Loose head prop	11	295.4 (163.6-533.4)	186	15.2 ±21.4	333.0 (288.4-384.4)	4	107.4 (40.3-286.2)	159	39.8 ±21.6[g]	284.6 (243.7-332.5)
2. Hooker	7	188.0 (89.6-394.3)	29	4.1 ±2.8[ekm]	51.9 (36.1-74.7)	0	0.0 –	0	0.0 -	0.0 -
3. Tight head prop	13	349.1 (202.7-601.2)[h]	94	7.2 ±10.7[km]	168.3 (137.5-206.0)	2	53.7 (13.4-214.7)	57	28.5 ±16.3	102.0 (78.7-132.3)
4. Left lock	7	188.0 (89.6-394.3)	28	4.0 ±2.3[km]	50.1 (34.6-72.6)	1	26.9 (3.8-190.6)[eh]	8	8.0 -	0.0 -
5. Right lock	10	268.5 (144.5-499.1)	232	23.2 ±28.7	415.3 (365.2-472.4)	5	134.3 (55.9-322.6)	220	44.0 ±27.9	14.3 (7.2-28.6)
6. Blind side flanker	13	349.1 (202.7-601.2)[h]	323	24.8 ±47.7[b]	578.2 (518.5-644.9)	8	214.8 (107.4-429.6)[d]	302	34.3 ±55.5[h]	393.8 (345.1-449.5)
7. Open side flanker	7	188.0 (89.6-394.3)	168	24.0 ±38.9	300.8 (258.5-349.8)	4	107.4 (40.3-286.2)	160	40.0 ±47.2	540.6 (483.0-605.2)
8. No. 8	10	268.5 (144.5-499.1)	116	11.6 ±11.4	207.7 (173.1-249.1)	5	134.3 (55.9-322.6)	100	20.0 ±10.7[ah]	286.4 (245.3-334.4)
9. Half back	4	107.4 (40.3-286.2)[cel]	74	18.5 ±10.3	132.5 (105.5-166.4)	3	80.6 (26.0-249.8)	70	23.3 ±4.5[eg]	179.0 (147.2-217.8)
10. First five eight	8	214.8 (107.4-429.6)	110	13.8 ±23.6	196.6 (163.4-237.4)	2	53.7 (13.4-214.7)	91	45.5 ±34.6	162.9 (132.7-200.1)
11. Left Wing	8	214.8 (107.4-429.6)	218	27.3 ±35.0	390.3 (341.7-445.7)	4	107.4 (40.3-286.2)	201	50.3 ±25.9[l]	359.8 (313.4-413.2)
12. Second five eight	11	295.4 (163.6-533.4)	108	9.8 ±10.6	193.3 (160.1-233.5)	3	80.6 (26.0-249.8)	40	20.0 ±1.4	71.6 (52.5-97.6)
13. Centre	7	188.0 (89.6-394.3)	125	17.9 ±14.8[bcdl]	223.8 (187.8-266.7)	5	134.3 (55.9-322.6)	118	27.3 ±12.6	211.2 (176.4-253.0)
14. Right Wing	12	322.2 (183.0-567.4)[e]	152	12.7 ±24.5[k]	272.1 (232.1-319.0)	3	80.6 (26.0-249.8)	110	36.7 ±46.2[i]	196.6 (163.4-237.4)
15. Fullback	10	268.5 (144.5-499.1)	318	31.8 ±26.2[bcd]	569.3 (510.0-635.4)	8	214.8 (107.4-429.6)[d]	312	39.0 ±24.2	558.5 (499.9-624.1)
Player group										
Front Row Forwards	41	275.2 (202.7-373.8)	540	12.8 ±19.7[o]	966.7 (888.5-1,051.8)	12	80.6 (45.7-141.9)	444	37.0 ±23.4	794.8 (724.2-872.3)
Back Row Forwards	37	248.4 (180.0-342.8)	636	17.2 ±33.4	1,138.6 (1,053.4-1,230.6)	17	114.1 (70.9-183.6)	562	33.1 ±44.8	1,006.1 (926.3-1,092.8)
Inside Backs	30	201.4 (140.8-288.0)	417	13.9 ±15.6	746.5 (678.2-821.7)	13	87.3 (50.7-150.3)	319	26.6 ±16.1	571.1 (511.7-637.3)
Outside Backs	30	268.5 (187.8-384.1)	688	22.9 ±28.5[n]	1,231.7 (1,143.0-1,327.2)	15	134.3 (80.9-222.7)	623	41.5 ±30.6	1,115.3 (1,031.1-1,206.4)
Player role										
Forwards	78	261.8 (209.7-326.9)	1,176	14.8 ±26.9	2,105.3 (1,988.3-2,229.1)	29	97.3 (67.6-140.1)	1,006	34.7 ±37.0	1,800.9 (1,693.0-1,915.7)
Backs	60	230.2 (178.7-296.4)	1,105	18.4 ±23.2	1,978.2 (1,864.9-2,098.3)	28	107.4 (74.2-155.6)	942	34.9 ±25.9	1,686.4 (1,582.0-1,797.6)
Total	**138**	**247.0 (209.1-291.9)**	**2,281**	**15.3 ±54.2**	**4,083.4 (3,919.2-4,254.5)**	**57**	**30.3 (23.4-39.3)**	**1,948**	**34.8 ±31.9**	**3,487.3 (3,335.8-3,645.6)**

n = number; CI = Confidence Interval; SD = Standard Deviation; Significant difference (*p*<0.05) than (a) = Loose-head Prop; (b) = Hooker; (c) = Tight-head Prop; (d) = Left Lock; (e) = Blindside flanker; (f) = Openside flanker; (g) = No. 8; (h) = Halfback; (i) = Left wing; (j) = second five-eight; (k) = Centre; (l) = Right wing; (m) = Fullback; (n) = Front-row Forwards; (o) = Outside Backs.

For time-loss injuries, the no. 8 recorded a significantly lower mean (20.0 ±10.7 days; 286.4 [95% CI: 245.3 to 334.4] per 1,000 match-hrs) injury burden than the loose-head prop (39.8 ±21.6 days; 284.6 [95% CI: 243.7 to 332.5] per 1,000 match-hrs; $t_{(3)}$=3.5; p=0.0383; d=1.16) and halfback (23.3 ±4.5 days; 179.0 [95% CI: 147.2 to 217.8] per 1,000 match-hrs ;$t_{(2)}$=-7.2; p=0.0187; d=0.40) (see Table 12). Although the tight-head prop and blind-side flanker recorded the highest total injury incidence (349.1 [95% CI: 202.7 to 601.2] per 1,000 match hrs.), the fullback recorded the highest mean injury burden (31.8 ±26.2 days; 569.3 [95% CI: 510.0 to 635.4] per 1,000 match-hrs) for total injuries. This was similar for time-lost injuries with the fullback recording the highest total (312 days) and mean injury burden (39.0 ±24.2 days; 558.5 [95% CI: 499.9 to 624.1] per 1,000 match-hrs).

Injury site

There were notably more total knee injuries (48.3 [95% CI: 33.1 to 70.5) per 1,000 match-hrs.) than neck (23.3 [95% CI: 13.5 to 40.1] per 1,000 match-hrs; RR: 2.1 [95% CI: 1.1 to 4.0]; p=0.0269), shoulder (21.5 [95% CI: 12.2 to 37.8] per 1,000 match-hrs; RR: 2.3 [95% CI: 1.2 to 4.4]; p=0.0163) or injuries to the head (19.7 [95% CI: 10.9 to 35.6] per 1,000 match-hrs; RR: 2.5 [95% CI: 1.2 to 4.9]; p=0.0094) (see Table 13). There were more time-loss injuries to the head (16.1[95% CI: 8.4 to 31.0] per 1,000 match-hrs.) than wrist (3.6 [95% CI: 0.9 to 14.3] per 1,000 match-hrs; RR: 4.5[95% CI: 1.0 to 20.7]; p=0.0348) elbow (1.8 [95% CI: 0.3 to 12.7] per 1,000 match-hrs; RR: 9.0[95% CI: 1.1 to 70.8]; p=0.0114) and lower leg injuries (1.8 [95% CI: 0.3 to 12.7] per 1,000 match-hrs; RR: 9.0[95% CI: 1.1 to 70.8]; p=0.0114).

Table 13: Anatomical location of injuries that occurred in an amateur domestic women's rugby union team in New Zealand over two consecutive years for total injuries and time-loss injuries. Data are reported as number of injuries recorded, rates per 1,000 match hours with 95% confidence intervals, number of days lost, mean number of days lost with standard deviation and rates per 1,000 match hours with 95% confidence intervals.

	Total Injuries					**Time-loss Injuries**				
	Injury Incidence		**Injury Burden**			**Injury Incidence**		**Injury Burden**		
		Rate		**Days**	**Rate**		**Rate**		**Days**	**Rate**
	n=	**Mean (95% CI)**	**Total**	**Mean ±SD**	**Mean (95% CI)**	**n=**	**Mean (95% CI)**	**Total**	**Mean ±SD**	**Mean (95% CI)**
Head/Neck										
Total	**35**	**62.7 (45.0-87.3)[cd]**	**380**	**13.0 ±14.7**	**680.3 (615.2-752.2)**	**16**	**26.9 (16.2-44.5)[d]**	**328**	**30.7 ±8.7**	**587.2 (527.0-654.3)**
Head	11	19.7 (10.9-35.6)[ghilmprstuyz124]	279	26.3 ±12.1	499.5 (444.2-561.6)	9	16.1 (8.4-31.0)[lnprswy134]	270	31.1 ±6.2	483.4 (429.0-544.6)
Eye	7	12.5 (6.0-26.3)[fhsu2]	16	2.3 ±0.8	28.6 (17.5-46.8)	0	0.0 -	0	0.0 -	0.0 -
Ear	1	1.8 (0.3-12.7)[efjqux]	5	5.0 -	9.0 (3.7-21.5)	0	0.0 -	0	0.0 -	0.0 -
Nose	2	3.6 (0.9-14.3)[ejux]	3	1.5 ±0.7	5.4 (1.7-16.7)	0	0.0 -	0	0.0 -	0.0 -
Mouth	1	1.8 (0.3-12.7)[efjqux]	1	1.0 -	1.8 (0.3-12.7)	0	0.0 -	0	0.0 -	0.0 -
Neck	13	23.3 (13.5-40.1)[ghilmprstyz1234]	76	9.5 ±14.5	136.1 (108.7-170.4)	7	12.5 (6.0-26.3)[nrswy34]	58	29.0 ±21.2	103.8 (80.3-134.3)
Upper Limb										
Total	**41**	**73.4 (54.0-99.7)[cd]**	**706**	**19.1 ±27.5**	**1,263.9 (1,174.0-1,360.6)**	**18[d]**	**32.2 (20.3-51.1)[d]**	**586**	**36.8 ±32.9**	**1,049.1 (967.5-1,137.5)**
Shoulder	12	21.5 (12.2-37.8)[u]	163	13.6 ±11.0	291.8 (250.3-340.2)	9	16.1 (8.4-31.0)[lnprswy134]	147	18.4 ±10.5	263.2 (223.9-309.3)
Clavicle	2	3.6 (0.9-14.3)[ejux]	27	13.5 ±4.9	48.3 (33.1-70.5)	2	3.6 (0.9-14.3)[eku]	27	13.5 ±4.9	48.3 (33.1-70.5)
Upper Arm	2	3.6 (0.9-14.3)[ejux]	2	2 -	3.6 (0.9-14.3)	0	0.0 -	0	0.0 -	0.0 -
Elbow	5	9.0 (3.7-21.5)[ux]	30	7.5 ±5.7	53.7 (37.6-76.8)	1	1.8 (0.3-12.7)[ejku]	16	16.0 -	28.6 (17.5-46.8)
Lower Arm	6	10.7 (4.8-23.9)[ux]	17	4.3 ±3.3	30.4 (18.9-49.0)	0	0.0 -	0	0.0 -	0.0 -
Wrist	3	5.4 (1.7-16.7)[ejux]	192	64.0 ±53.9	343.7 (298.4-395.9)	2	3.6 (0.9-14.3)[eku]	160	95.0 ±7.1	286.4 (245.3-334.4)
Finger	8	14.3 (7.2-28.6)[gisu2]	173	21.6 ±30.2	309.7 (266.8-359.5)	3	5.4 (1.7-16.7)[u]	146	52.0 ±31.2	261.4 (222.2-307.4)
Thumb	3	5.4 (1.7-16.7)[ejux]	102	34.0 ±48.5	182.6 (150.4-221.7)	1	1.8 (0.3-12.7)[ejku]	90	90.0 -	161.1 (131.0-198.1)
Lower Limb										
Total	**63**	**112.8 (88.1-144.4)[abd]**	**1,067**	**17.9 ±29.7**	**1,910.1 (1,798.9-2,028.3)**	**26[d]**	**46.5 (31.7-68.4)[d]**	**933**	**38.1 ±38.0**	**1,670.2 (1,566.4-1,780.9)**
Quadriceps	1	1.8 (0.3-12.7)[efjqux]	14	14.0 -	25.1 (14.8-42.3)	1	1.8 (0.3-12.7)[ejku]	14	14.0 -	25.1 (14.8-42.3)
Hamstring	2	3.6 (0.9-14.3)[ejux]	8	4.0 ±2.8	14.3 (7.2-28.6)	0	0.0 -	0	0.0 -	0.0 -
Knee	27	48.3 (33.1-70.5)[efghiklmnopqrstvwyz1234]	589	22.1 ±35.7	1,054.4 (972.6-1,143.1)	12	21.5 (12.2-37.8)[lnpqrsy134]	513	44.4 ±45.1	918.4 (842.2-1,001.4)
Patella	6	10.7 (4.8-23.9)[ux]	71	14.2 ±9.4	127.1 (100.7-160.4)	5	9.0 (3.7-21.5)	84	21.0 ±2.0	150.4 (121.4-186.2)
Lower Leg	8	14.3 (7.2-28.6)[u]	38	5.4 ±6.6	68.0 (49.5-93.5)	1	1.8 (0.3-12.7)[ejku]	20	20.0 -	35.8 (23.1-55.5)
Ankle	15	26.9 (16.2-44.5)[ghilmnoprstvyz1234]	324	21.6 ±33.4	580.0 (520.2-646.7)	6	10.7 (4.8-23.9)	288	48.0 ±41.5	515.6 (459.3-578.7)
Achilles	2	3.6 (0.9-14.3)[ejux]	21	10.5 ±4.9	37.6 (24.5-57.7)	1	1.8 (0.3-12.7)[ejku]	14	14.0 -	25.1 (14.8-42.3)
Foot	2	3.6 (0.9-14.3)[ejux]	2	2.0 -	3.6 (0.9-14.3)	0	0.0 -	0	0.0 -	0.0 -
Chest/Back/Other										
Total	**10**	**17.9 (9.6-33.3)[abc]**	**128**	**12.8 ±12.6**	**229.1 (192.7-272.5)**	**4[bc]**	**7.2 (2.7-19.1)[abc]**	**101**	**25.3 ±11.0**	**180.8 (148.8-219.7)**
Sternum	3	5.4 (1.7-16.7)[ejux]	65	21.7 ±18.0	116.4 (91.2-148.4)	2	3.6 (0.9-14.3)[eku]	61	30.5 ±13.4	109.2 (85.0-140.4)
Lower Back	1	1.8 (0.3-12.7)[efjqux]	7	7.0 -	12.5 (6.0-26.3)	0	0.0 -	0	0.0 -	0.0 -
Ribs	4	7.2 (2.7-19.1)[jux]	40	10.0 ±10.9	71.6 (52.5-97.6)	1	1.8 (0.3-12.7)[ejku]	26	26.0 -	46.5 (31.7-68.4)
Pelvis	2	3.6 (0.9-14.3)[ejux]	16	8.0 ±8.5	28.6 (17.5-46.8)	1	1.8 (0.3-12.7)[ejku]	14	14.0 -	25.1 (14.8-42.3)
Total	**149**	**266.7 (227.2-313.2)**	**2,281**	**15.3 ±54.2**	**4,083.4 (3,919.2-4,254.5)**	**64**	**114.6 (89.7-146.4)**	**1,948**	**34.8 ±31.9**	**3,487.3 (3,335.8-3,645.6)**

CI = Confidence Intervals; Significant difference (p<0.05) than (a) = Head/Neck; (b) = Upper Limb; (c) = Lower Limb; (d) = Chest/Back/Other; (e) = Head; (f) = Eye; (g) = Ear; (h) = Nose; (i) = Mouth; (j) = Neck; (k) = Shoulder; (l) = Clavicle; (m) = Upper Arm; (n) = Elbow; (o) = Lower Arm; (p) = Wrist; (q) = Finger; (r) = Thumb; (s) = Quadriceps; (t) = Hamstring; (u) = Knee; (v) = Patella; (w) = Lower Leg; (x) = Ankle; (y) = Achilles; (z) = Foot; (1) = Sternum; (2) = Lower Back; (3) = Ribs; (4) = Pelvis

Table 14: Injury type, injury cause, and match period of injuries that occurred in an amateur women's rugby union team in New Zealand for total injuries and time-loss injuries over two consecutive years by injuries recorded, rates per 1,000 match hours with 95% confidence intervals, number of days lost, mean number of days lost with standard deviation.

	Total Injuries					**Time-Loss Injuries**				
	Injury Incidence		**Injury Burden**			**Injury Incidence**		**Injury Burden**		
	n=	**Rate Mean (95% CI)**	**Total**	**Days Mean ±SD**	**Rate Mean (95% CI)**	**n=**	**Rate Mean (95% CI)**	**Total**	**Days Mean ±SD**	**Rate Mean (95% CI)**
Injury type*										
Strains/Sprains	81	145.0 (116.6-180.3)[bcdefg]	980	14.4 ±24.4[bd]	1,754.4 (1,647.9-1,867.7)	35	62.7 (45.0-87.3)[bcdef]	813	30.1 ±33.2[d]	1,455.4 (1,358.7-1,559.0)
Contusion	30	53.7 (37.6-76.8)[acdefg]	213	5.1 ±5.2[adf]	381.3 (333.4-436.1)	3	5.4 (1.7-16.7)[a]	91	18.3 ±3.8[d]	162.9 (132.7-200.1)
Dislocation	9	16.1 (8.4-31.0)[ab]	115	16.4 ±13.5[deg]	205.9 (171.5-247.5)	7	12.5 (6.0-26.3)[a]	103	25.8 ±9.6[d]	184.4 (152.0-223.7)
Fracture	9	16.1 (8.4-31.0)[ab]	667	74.1 ±31.4[abcef]	1,194.1 (1,106.8-1,288.2)	9	16.1 (8.4-31.0)[a]	667	74.1 ±31.4[abcf]	1,194.1 (1,106.8-1,288.2)
Wounds	10	17.9 (9.6-33.3)[ab]	42	4.2 ±3.9[df]	75.2 (55.6-101.7)	1	1.8 (0.3-12.7)[a]	14	14.0 -	25.1 (14.8-42.3)
Concussion	9	16.1 (8.4-31.0)[ab]	260	28.9 ±3.7[bde]	465.4 (412.2-525.6)	9	16.1 (8.4-31.0)[a]	260	28.9 ±3.7[d]	465.4 (412.2-525.6)
Other	4	7.2 (2.7-19.1)[ab]	4	2.0 ±0.0[c]	7.2 (2.7-19.1)	0	0.0 -	0	0.0 -	0.0 -
Total	**151**	**270.3 (230.5-317.1)**	**2,281**	**16.5 ±26.0**	**4,083.4 (3,191.2-4,254.5)**	**64**	**114.6 (89.7-146.4)**	**1,948**	**34.8 ±31.9**	**3,487.3 (3,335.8-3,645.6)**
Injury cause										
Tackle Related	101	180.8 (14.8-219.7)[lmnopq]	1,748	17.1 ±22.2	3,129.3 (2,985.9-3,279.4)	47	84.1 (63.2-112.0)[lmnop]	1,512	33.2 ±25.2	2,706.8 (2,573.7-2,846.7)
Ball Carrier	68	121.7 (96.0-154.4)[jklmnopq]	1,215	20.2 ±25.2	2,175.1 (2,056.2-2,300.9)	34	60.9 (43.5-85.2)[jlmnop]	1,054	31.8 ±20.8	1,886.9 (1,776.3-2,004.3)
Tackler	33	59.1 (42.0-83.1)[iklmnopq]	533	16.6 ±22.7	954.2 (876.5-1,038.7)	13	23.3 (13.5-40.1)[ilmnop]	458	35.2 ±26.4	819.9 (748.2-898.5)
Collision Player	2	3.6 (0.9-14.3)[hij]	8	4.0 ±1.4	14.3 (7.2-28.6)	0	0.0 -	0	0.0 -	0.0 -
Ruck	11	19.7 (10.9-35.6)[hijkmno]	105	9.5 ±10.0	188.0 (155.2-227.6)	4	7.2 (2.7-19.1)[hij]	87	21.8 ±4.3	155.7 (126.2-192.2)
Maul	3	5.4 (1.7-16.7)[hij]	108	36.0 ±66.5	193.3 (160.1-233.5)	1	1.8 (0.3-12.7)[hij]	100	100.0 -	179.0 (147.2-217.8)
Scrum	3	5.4 (1.7-16.7)[hij]	24	8.0 ±7.1	43.0 (28.8-64.1)	1	1.8 (0.3-12.7)[hij]	16	16.0 -	28.6 (17.5-46.8)
Slip	2	3.6 (0.9-14.3)[hij]	26	13.0 -	46.5 (31.7-68.4)	1	1.8 (0.3-12.7)[hij]	21	21.0 -	37.6 (24.5-57.7)
Twist	8	14.3 (7.2-28.6)[hij]	231	28.9 ±66.1	413.5 (363.5-470.5)	3	5.4 (1.7-16.7)[hij]	212	70.7 ±118.1	379.5 (331.7-434.2)
Other/Unknown	8	14.3 (7.2-28.6)[hij]	31	4.1 ±2.0	55.5 (39.0-78.9)	0	0.0 -	0	0.0 -	0.0 -
Match Quarter										
First Quarter	13	93.1 (54.1-160.3)[stu]	179	12.5 ±14.9	320.1 (276.8-371.0)	4	28.6 (10.8-76.3)[stu]	135	20.9 ±13.2	241.7 (204.2-286.1)
Second Quarter	38	272.1 (198.0-374.0)[r]	492	12.2 ±16.7	880.8 (806.3-962.1)	16	114.6 (70.2-187.0)[r]	413	23.7 ±20.8	739.3 (671.4-814.2)
Third Quarter	42	300.8 (222.3-407.0)[r]	591	15.1 ±21.5	1,058.0 (976.1-1,146.8)	16	114.6 (70.2-187.0)[r]	478	36.0 ±25.9	855.7 (782.3-936.0)
Fourth Quarter	45	322.2 (240.6-431.6)[r]	1,019	23.2 ±35.4	1,824.2 (1,715.6-1,939.7)	21	150.4 (98.0-230.6)[r]	922	46.1 ±42.7	1,650.6 (1,574.4-1,760.6)
Match Half										
First Half	51	182.6 (138.8-240.3)[w]	671	12.1 ±15.9	1,201.2 (1,113.7-1,295.6)	20	71.6 (46.2-111.0)[w]	548	25.7 ±19.1	981.0 (902.2-1,066.7)
Second half	87	311.5 (252.5-384.3)[v]	1,610	19.3 ±29.8	2,882.2 (2,744.8-3,026.5	37	132.5 (96.0-182.8)[v]	1,400	42.1 ±36.9	2,506.3 (2,378.4-2,641.1)
Total	**138**	**247.0 (209.1-291.9)**	**2,281**	**15.3 ±54.2**	**4,083.4 (3,191.2-4,254.5)**	**57**	**102.0 (78.7-132.3)**	**1,948**	**34.8 ±31.9**	**3,487.3 (3,335.8-3,645.6)**

CI = Confidence Interval; * = Some injuries resulted in multiple injury types; Significant difference (p<0.05) than (a) = Strains/Sprains; (b) = Contusion; (c) = Dislocation; (d) = Fracture; (e) = Wounds; (f) = Concussion; (g) = Other; (h) = Tackle (i) =Ball Carrier; (j) = Tackler; (k) = Collision Player; (l) = Ruck; (m) = Maul; (n) = Scrum; (o) = Slip; (p) = Twist; (q) = Other/Unknow; (r) = First Quarter; (s) = Second Quarter; (t) = Third Quarter; (u) = Fourth Quarter; (v) = First Half; (w) = Second Half.

The knee recorded the highest injury burden in total days lost for total (589 days; 1,054.4 [95% CI: 972.6 to 1,143.1] per 1,000 match-hrs.) and time-loss (513 days; 918.4 [95% CI: 842.2 to 1,001.4] per 1,000 match-hrs.) injuries, but the wrist (95.0 ±7.1 days; 286.4 [95% CI: 245.3 to 334.4] per 1,000 match-hrs) and finger (52.0 ±31.2 days; 261.4 [95% CI: 222.2 to 307.4] per 1,000 match-hrs) recorded the highest mean time-loss injury burden. When viewed by injury region, the lower limb recorded the highest total days lost (1067 days; 1,910.1 [95% CI: 1,798.9 to 2,028.3] per 1,000 match-hr) but the upper limb recorded the highest total mean (19.1 ±27.5 days; 1,263.9 [95% CI: 1,174.0 to 1,360.6] per 1,000 match-hrs) days lost.

Injury type

Strains and sprains were the most common total (200.5 [95% CI: 151.1 to 266.1] per 1,000 match-hrs.) and time-loss injuries (62.7 [95% CI: 45.0 to 87.3] per 1,000 match-hrs) recorded (see Table 14). There were significantly more time-loss strains and sprains injuries (62.7 [95% CI: 45.0 to 87.3] per 1,000 match-hrs.) than concussions (16.1 [8.4 to 31.0] per 1,000 match-hrs; RR: 3.9 [95% CI: 1.9 to 8.0]; p=0.0001), fractures (16.1 [8.4 to 31.0] per 1,000 match-hrs; RR: 3.9 [95% CI:1.09 to 8.0]; p=0.0001) and dislocations (12.5 [95% CI: 6.0 to 26.3] per 1,000 match-hrs; RR: 5.0 [95% CI: 2.2 to 11.2]; p<0.0001) (see Table 14). Fractures recorded a significantly higher mean total injury burden (74.1 ±31.4 days; 1,194.1 [95% CI: 1,106.8 to 1,288.2] per 1,000 match-hrs), when compared with concussion (28.9 ±3.7 days; 465.4 [95% CI: 412.2 to 525.6] per 1,000 match-hrs; $t_{(5)}$=4.0; p=0.0099; d=2.02), dislocations (16.4 ±13.5 days; 205.9 [95% CI: 171.5 to 247.5] per 1,000 match-hrs; $t_{(6)}$=-4.9; p=0.0026; d=2.39) and sprains and strains (14.4 ±24.4 days; 1,754.4 [1,647.9 to 1,867.7] per 1,000 match-hrs; $t_{(8)}$=-6.3; p=0.0002; d=2.12).

Injury cause

There was a two-fold difference in the total injuries recorded to the ball carrier (121.7 [95% CI: 96.0 to 154.4] per 1,000 match-hrs) compared with the tackler (59.1 [95% CI: 42.0 to 83.1] per 1,000 match-hrs; RR: 2.1 [95% CI: 1.6 to 3.1]; p=0.0005) (see Table 14). There was nearly a three-fold difference in the time-loss injuries to the ball carrier (60.9 [95% CI: 43.5 to 85.2] per 1,000 match-hrs.) compared with the tackler (23.3 [95% CI: 13.5 to 40.1] per 1,000 match-hrs; RR: 2.6 [95% CI: 1.4 to 4.9]; p=0.0022). Although the tackle recorded a mean total (17.1 ±22.2 days; 3,129.3 [95% CI: 2,985.9 to 3,279.4] per 1,000 match-hrs) and time-loss (33.2 ±25.2 days; 2,706 [95% CI: 2,573.7 to 2,846.7] per 1,000 match-hrs.) injury burden, the maul recorded the highest mean total (36.0 ±66.5 days; 193.3 [95% CI: 160.1 to 233.5] per 1,000 match-hrs.) and time loss (100 days; 179.0 [95% CI: 147.2 to 217.8] per 1,000 match-hrs.) injury burden.

Match period

The first quarter of matches recorded significantly fewer total injuries (93.1 [95% CI: 54.1 to 160.3] per 1,000 match-hrs.) than the second (272.1 [95% CI: 198.0 to 374.0] per 1,000 match-hrs; RR: 2.9 [95% CI: 1.6 to 5.4]; p=0.0005), third (300.8 [95% CI: 222.3 to 407.0] per 1,000 match-hrs; RR: 3.2 [95% CI: 1.8 to 6.0]; p=0.0001) and fourth (322.2 [95% CI: 240.6 to 431.6] per 1,000 match-hrs; RR: 3.5 [95% CI: 1.9 to 6.3]; p<0.0001) quarters of matches (see Table 14). There were more time-loss injuries recorded in the second (132.5 [95% CI: 96.0 to 182.8] per 1,000 match hrs.) than the first half (71.6 [95% CI: 46.2 to 111.0] per 1,000 match-hrs; RR: 1.9 [95% CI: 1.1 to 3.1]; p=0.0243) of matches. Although the mean injury burden was higher in the second, when compared with the first halves of matches for total (19.3 ±29.8 days (2,882.2 [95% CI: 2,744.8 to 3,026.5] per 1,000 match-hrs) vs. 12.1 ±15.9 days (1,201.2 [95% CI: 1,113.7 to 1,295.6] per 1,000 match-hrs); $t_{(53)}$=-1.7; p=0.0908; d=0.30) and time-loss injuries (42.1 ±36.9 days (2,506.3 [95% CI: 2,378.4 to 2,641.1] per 1,000 match-hrs) vs. 25.7 ±19.1 days (981.0 [95% CI: 902.2 to 1,066.7] per 1,000 match-hrs); $t_{(19)}$=-1.8; p=0.0854; d=0.56), these were not significant

Discussion

This prospective observational study undertook to document the incidence of match injuries occurring in an amateur women's rugby team over two consecutive domestic competition seasons. The principal findings of this study were: 1) A total injury incidence of 247.0 (95% CI: 209.1 to 291.9) per 1,000 match-hrs and a total injury burden of 15.3 ±54.2 days or 4,083.4 (3,191.2 to 4,254.5) per 1,000 match-hrs; (2) A time-lost injury incidence of 102.0 (95% CI: 78.7 to 132.3) per 1,000 match-hrs and a time-loss injury burden of 34.8 ±31.9 days or 3,487.3 (95% CI: 3,335.8 to 3,645.6) per 1,000 match-hrs; (3) the lower limb sustained the highest injury incidence with the knee having the greatest proportion of these injuries; (4) the tackle recorded the highest total and time-lost injury rate and injury burden, and being tackled was associated with a notably higher injury incidence than any other match event for total and time-loss injuries; (5) sprains and strains recorded the highest total and time-lost injury rate and injury burden; and (6) the lower limb body region recorded the most days lost and had the highest mean days lost per injury for total and time-loss injuries.

Comparative injury incidence

The time-loss injury incidence recorded in this study (102.0 [95% CI: 78.7 to 132.3] per 1,000 match-hr) were higher than professional men's rugby (81 [95% CI: 63 to 105] per

1,000 match-hr),[322] amateur men's rugby (46.0 [95% CI: 34.4 to 59.2] per 1,000 player hrs.),[332] and children and adolescent (26.7 [95% CI: 13.2 to 54.1] per 1,000 player-hr)[94] rugby injury-incidence. As can be seen by the comparisons between the current study and those reporting on the different levels of male rugby, the injury incidence of amateur women's rugby in New Zealand is higher than previously reported time-loss injury incidence. Consequently, it may not be appropriate to generalise the findings of male rugby studies to those of female rugby match studies, and specific research is required in order to identify and develop female rugby specific injury prevention strategies.

As can be seen in Table 10, the mean player age increased from 24.2 ±6.0 yrs. in 2018 to 28.9 ±8.0 yrs. in 2019, with the return of the older players to support the club and the competition, as some teams withdrew due to low player numbers. This resulted in some clubs amalgamating in order to participate in the competition, but resulted in fewer rounds, games being cancelled and fewer people coming to training, yet turning up and playing at matches. The practice of turning up to matches with no preparation for the rigors of the activity is not ideal. However, this does occur due to a variety of reasons outside the scope of this research but does have an impact on the injury incidence, especially if the players are returning from an injury or have not undertaken any form of training. The outcome of this may be a possible reason for the findings on injury insurance claims,[264] adult females (21 to 30 yrs. old) had similar rates of injury to male players but female players aged 31 to 40 yrs. old had a substantially higher rate of injuries to that of male players of the same age.

Player position

The most common player positions to be injured for total injuries were the tight-head prop, blind-side flanker (349.1 [95% CI: 202.7 to 601.2] per 1,000 match-hrs.) and the right wing (322.2 [95% CI: 183.0 to 567.4] per 1,000 match-hrs.). This resulted in Forwards (261.8 [95% CI: 209.7 to 326.9] per 1,000 match-hrs.) recording a non-significant higher total injury incidence than Backs (230.2 [95% CI: 178.7 to 296.4] per 1,000 match-hrs.). However, for time-loss injuries, the most commonly injured player positions were the blind-side flanker, fullback (214.8 [95% CI: 107.4 to 429.6] per 1,000 match-hrs.), right lock, No. 8, and centre (134.3 [95% CI: 55.9 to 322.6] per 1,000 match-hrs.). The finding that Forwards recorded more total injuries than Backs is similar to other studies[175, 285] reporting on women's rugby union.

The higher contact and collision demands in rugby of Forwards,[74, 332] combined with the greater body mass and increased momentum,[265, 268] have been suggested as possible explanations for the higher incidence of injury in Forwards than Backs.[31] The finding that Backs recorded more time-loss injuries was not expected. A possible explanation for some of the findings recorded may be that some players competed with an injury that had not been appropriately managed. It has been postulated that previous injury is a risk factor for a subsequent injury occurring.[71, 138] This may be related to alterations in the player's intrinsic risk factors (e.g. movement pattern alterations, loss of balance etc.) that can modify the individual player's predisposition to injury.[103, 232] Another aspect unique to this cohort were that younger lighter players with less playing experience were often placed into the Backs positions and were, at times expected to know how to tackle and defend against more experienced, larger players. Further research is warranted to identify if this finding is unique to this cohort.

Injury site

The knee was most commonly injured for both total (48.3 [95% CI: 33.1 to 70.5] per 1,000 match-hrs.) and time-loss (21.5 [95% CI: 12.2 to 37.8] per 1,000 match-hrs.) injuries. As a result, the lower limb was the most commonly recorded injury region for both total (112.8 [95% CI: 88.1 to 144.4] per 1,000 match-hrs.) and time-loss (46.5 [95% CI: 31.7 to 68.4] per 1,000 match-hrs.) injuries over the study. This was similar to previous rugby injury studies[36, 322, 332] where the lower limb sustained the most injuries. In reporting on amateur male rugby union,[332] the knee had a pooled incidence of 3.8 [95% CI: 3.1 to 4.5] per 1,000 player hrs., which was considerably lower when compared with the current study. The finding that the knee and lower limb were the most commonly recorded total and time-loss injury site, and region was not unexpected, as previous studies have reported this.[36, 79, 188]

Although there were a number of time-loss injuries to the knee, there were no anterior cruciate ligament (ACL) injuries, but there were a high number of medial and lateral collateral ligament strains and patella dislocation injuries and this was unexpected. ACL injury incidence in females is reportedly two to eight times higher compared with males. This difference has been related to effects of the menstrual cycle, different stages of the menstrual cycle and anatomical aspects.[293, 324, 325] This is reportedly similar for ligaments and tendons[324, 325] and may have been reflected in the findings of the high number of knee injuries recorded. However, no record of the menstrual cycle or oral contraceptive use was recorded during this study and future studies may consider this aspect to be included.

Injury type

Strains and sprains were the most common injuries recorded, which is similar to previous studies reporting on rugby union injuries for male[322, 332] and female participants.[188] This was not unexpected as the game of rugby is a physical collision contact sport. This was similar to amateur male rugby union, but when compared with the total (145.0 [95% CI: 116.6 to 180.3] per 1,000 match-hrs.) and time-loss (62.7 [95% CI: 45.0 to 87.3] per 1,000 match-hrs.) rate, this was considerably higher than the pooled amateur rugby union sprains (6.3 [95% CI: 5.6 to 6.9] per 1,000 player hrs.) and strains (4.6 [95% CI: 4.2 to 5.1] per 1,000 player hrs.).[332] In the study reporting on New Zealand rugby union injury insurance claims over a 12 yr. period,[264] female players over 21 years old had a higher rate of soft tissue injuries (RR range:1.1 to 1.6) than male players.

The difference may be related to the possibility of some players not recording their injury through the national accident insurance scheme, but instead managing their own injuries as most of the teams in the women's competition do not have any form of medical coverage on the sideline, unlike most senior male rugby union matches where there is a physiotherapist or a designated trained sports medic with the team. Throughout the duration of this study the lead researcher was the only trained health professional at the women's games and provided medical coverage for the opposition teams each week as well.

The incidence of concussion (16.1 [95% CI: 8.4 to 31.0] per 1,000 match-hrs.) over the study was higher than previous studies reporting on women's rugby union at the World Cup (3.5 [95% CI: 1.7 to 7.0] per 1,000 match hrs)[302] and collegiate rugby union (1.6 [95% CI: 1.1 to 2.3] per 1,000 player match-hrs.).[175] The mean time away from match activities for concussions was 28.9 ±3.7 days, which was similar to a previous study[168] where the majority of concussions took 28 days post-injury to recover. This was in conflict with the Concussion in Sport Consensus (CISC) where it was reported that 80% to 90% of all concussions recover in seven to 10 days.[223, 224] Based on the CISC, the New Zealand Rugby concussion guidelines identified that players may return to match activities on the 21st day post injury with medical clearance.[283]

No players in this study with an identified concussion were allowed to commence contact training in preparation for match participation until they had equalled or surpassed (faster) their baseline King-Devick test. No player with a concussion returned to their baseline before 21 days post injury. No player was allowed to return to match participation for any injury until they had completed two contact training sessions and were symptom free and, in the case of a concussion, there were no worsening (slower) of their King-Devick test time from their baseline.

Injury cause

The tackle was recorded as being the most common injury cause in this study. This finding was not unexpected given that the tackle is the most common contact event in rugby[95, 322] and is reportedly[2, 36, 266] one of the most cited high injury risk events in rugby. Changes in the level of proficiency by the ball carrier and the tackler have been reported[43] to be associated with a reduction in the risk of injury during tackle events. The mean playing experience of the current cohort of women's rugby players was 4.3 yrs. and, in the second year of this study, there were far more players with minimal or no previous playing experience. In addition, the coaches were previous premier amateur rugby players and there was an expectation that the players at this level of competition would be proficient in tackle technique, so the primary focus was on match tactics during the training sessions. Further research is warranted to identify tackle technique training and the need for specific coaching for women in comparison with male rugby.

Match period

The finding that there were notably fewer injuries in the first quarter of matches when compared with other match quarters may be an indicator that fatigue is indicated in the aetiology of the injuries that were recorded.[157] Factors such as playing experience, hydration, nutrition, biomechanical differences, physique, low maximal aerobic power, training time prior to match participation, training load and low 10m and 40m speed times have all be associated with an greater risk of an injury occurring.[111, 209, 210] Compared to male rugby, women's rugby is still a relatively new activity and players have not had the previous playing experience when compared to males of the same age. This decreased exposure, combined with hormonal and physiological changes that women experience may have a large influence on their physiological attributes when they begin to participate in women's rugby union. In addition, some of the players within this cohort were 48 yrs. and they were only able to compete in the one women's senior competition.

Injury burden

The mean number of total days missed was 15 days (4,083.4 per 1,000 match-hrs). When viewed by time-loss injuries, this doubled to 35 days (3,487.3 per 1,000 match-hrs). This was similar to professional male rugby, where the mean days lost varied from 13 to 27[100, 174, 322] days lost, but less than the mean severity of the Rugby World Cup for women[302] of 55 days per injury. Unfortunately, other studies reporting on women's rugby union match injuries[46, 175, 285] did not report the mean injury burden, with many not reporting injury burden at all. The mean days lost reported in the current study were calculated as previously identified.[30, 99] Women's rugby has grown in popularity in recent years with over 2 million women participating at the community and elite levels of participation around the globe. It is clear that the reporting of injury surveillance has not kept pace with the rapid rise in participation.

Since completing the data collection, community-based injury surveillance guidelines have been published[37] and this included data collection on missed school or work which was not collected as part of the current data. Future studies reporting on amateur rugby injuries should consider incorporating this into the data collection to enable a more consistent approach to non-elite rugby injury surveillance.[37]

Limitations

The findings of this study are limited to a single amateur women's rugby union team over two consecutive domestic competition seasons. However, there are very few studies of women's rugby and the injuries sustained. The incidence of injuries may not be reflective off all amateur women's rugby union teams given this was a sample of New Zealand players.

Conclusion

This prospective observational study undertook to document the incidence of match injuries occurring in an amateur women's rugby team over two consecutive domestic competition seasons. The injury incidence of amateur women's rugby in New Zealand is more than double than male rugby for both the total and time-loss injury incidence. The most common player positions to be injured for total injuries were the tight-head prop, blind-side flanker and the right wing. the lower limb was the most commonly recorded injury region for both total and time-loss injuries. The incidence of concussion over the study was higher than previous studies reporting on women's rugby union at the World Cup and collegiate rugby union. This study highlights the need for injury prevention support for amateur women's rugby union teams in New Zealand given the incidence of injuries.

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GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Douglas Alsitair King
Name/title of Primary Supervisor:	A/Prof Matt Barnes
In which chapter is the manuscript /published work:	Chapter 5

Please select one of the following three options:

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- Please provide the full reference of the Research Output:

King, D., Hume, P.A., Clark, T.N., Foskett, A. & Barnes, M.J. Incidence of match injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons. Advances in Orthopaedics and Sports Medicine, 2020. 2(129): 12 pages

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Chapter 6: Summary/Conclusions

Introduction

At the commencement of this thesis the published papers reporting on the injury incidence[19, 46, 57, 79, 101, 175, 217, 257, 285, 302] and the movement analysis[25, 297, 314] in women's rugby union were identified. Interestingly, there were no New Zealand based studies on women's rugby union. Of the studies that had been identified for injury epidemiology and movement analysis, these had utilised different methodological approaches to reporting their findings and this limited any inter-study comparisons. In addition, some of the injury incidence papers[19, 46, 57, 79, 175] were published prior to the publication of the "Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union".[98] More recently, and after the collection of data for this thesis, community-based injury surveillance guidelines have been published,[37] however no study to date has been identified utilising this guideline.

The data collected for the study in Chapter 3 was undertaken to establish a baseline of the movement analysis and heart rate responses of New Zealand amateur women's rugby union players. The differences between males and females in relative distance, high intensity running, and severe impacts remains relatively unknown.[11] However, the proposed mechanisms of these differences have included lower physical capacities of female athletes, when compared with male athletes, for relative distance and match running demands,[26] as well as the contrasting physical make-up and muscle architecture that may account for the differences in force production, high intensity running and impacts.[54] Given these differences in the distance travelled at high velocities and player absolute maximum velocity, it was also recommended that, for practical applications, these velocity zones are adjusted.[27] However, until these are reported and validated, for inter-study comparisons of movement demands of women and men, it has been recommended that the velocity zones remain consistent.[11]

The increased popularity of rugby union by female participants has seen the game grow, with over 2 million women participating under the same rules as their male counterparts at the community and elite levels of participation.[104] Despite the same rules for participation as males, females reportedly have higher injury risks,[18] even though they have lower physiological indices (e.g. reduced speed and less agility, lower muscular power, lower estimated maximal aerobic power), when compared with males.[196] Interestingly, injury patterns differ between males and females in other sports such as basketball,[72] football,[316] handball,[206] and rugby league[193] but there is a paucity of published studies reporting on women's injury patterns in rugby union and the identification of women appropriate movement demands velocity bands.

Primary aim of this research

The series of concurrent studies conducted in this thesis were aimed to broaden the knowledge base of the movement demands and the incidence and burden of training and match injuries in amateur women's rugby union in one district in New Zealand. To achieve this, a number of specific research questions were developed, and a brief summary of the principal findings are detailed below.

Research Question 1: **What are the movement demands and physiological responses of an amateur women's rugby union team in New Zealand?**

Principle findings (Study 1: Chapter 2):

- Players covered a mean distance of 3,546.6 ±1,329.2 m or 38.3 ±13.7 $m \cdot min^{-1}$ per-game;
- Inside backs covered a higher mean distance (3,920.7 ±1,437.3 m or 42.3 ±14.6 $m \cdot min^{-1}$) than back-row forwards (3,669.2 ±1,161.1 m or 39.0 ±12.0 $m \cdot min^{-1}$), outside backs (3,410.5 ±1,399.5 m or 37.2 ±14.7 $m \cdot min^{-1}$) and front-row forwards (3,189.2 ±1,195.7 m or 34.9 ±12.5 $m \cdot min^{-1}$) per-game;
- Although Forwards had a similar mean heart rate (149.9 ±25.1 $b \cdot pm^{-1}$) as Backs (148.7 ±18.7 $b \cdot pm^{-1}$), they recorded a higher max heart rate (190.6 ±34.3 $b \cdot pm^{-1}$) when compared with Backs (188.4 ±35.3 $b \cdot pm^{-1}$), but this was not significant.

Research Question 2: **What is the epidemiology of injury in women's rugby union?**

Principle findings (Study 2: Chapter 3):

- Ten articles regarding the incidence of injury in women's rugby union players were retrieved and included.
- The pooled incidence of injuries in women's rugby-15s was 19.6 (95% CI: 17.7-21.7) per 1,000 match-hr.
- Injuries in women's rugby-15s varied from 3.6 (95% CI: 2.5-5.3) per 1,000 playing-hr (including training and games) to 37.5 (95% CI: 26.5-48.5) per 1,000 match-hr.

- Women's rugby-7s had a pooled injury incidence of 62.5 (95% CI: 54.7-70.4) per 1,000 player-hr and the injury incidence varied from 46.3 (95% CI: 38.7-55.4) per 1,000 match-hr to 95.4 (95% CI: 79.9-113.9) per 1,000 match-hr.
- The tackle was the most commonly reported injury cause, with the ball carrier recording more injuries at the collegiate (5.5 [95% CI: 4.5 to 6.8] vs. 3.5 [95% CI: 2.7 to 4.6] per 1,000 player-game-hr; $\chi^2_{(1)}=6.7$; $p=0.0095$), and Rugby World Cup for women (RWC(W)) (2006: 14.5 [95% CI: 8.9 to 23.7] vs. 10.9 [95% CI: 6.2 to 19.2] per 1,000 match-hr; $\chi^2_{(1)}=0.6$; $p=0.4497$; 2010: 11.8 [95% CI: 6.9 to 20.4] vs. 1.8 [95% CI: 0.5 to 7.3] per 1,000 match-hr; $\chi^2_{(1)}=8.1$; $p=0.0045$) levels of participation.
- Concussions and sprains/strains were the most commonly reported injuries at the collegiate level of participation.

Research Question 3: **What is the incidence, site, type, and timing of training injuries in an amateur women's rugby union team in New Zealand?**

Principle findings (Study 3: Chapter 4):

- A total injury incidence of 11.4 (95% CI: 8.3 to 15.6) per 1,000 training-hrs;
- A time-loss injury incidence of 3.6 (95% CI: 2.0 to 6.3) per 1,000 training-hrs;
- The lower limb injury incidence was highest, with the ankle sustaining the greatest proportion of injuries;
- The tackle was associated with a higher injury incidence than any other training event;
- Sprains and strains recorded the highest injury incidence; and
- The lower limb body region resulted in most time-loss injury incidence.

Research Question 4: **What is the incidence, site, type, and timing of match injuries in an amateur women's rugby union team in New Zealand?**

Principle findings (Study 4: Chapter 5):

- Total injury incidence was 247.0 (95% CI: 209.1 to 291.9) per 1,000 match-hrs;
- Time-lost from rugby due to injuries was 102.0 (95% CI: 78.7 to 132.3) per 1,000 match-hrs;
- The lower limb sustained the highest injury incidence, with the knee having the greatest proportion of these injuries;
- The tackle recorded the highest injury rate, and being tackled was associated with a notably higher injury incidence than any other match event;
- Sprains and strains recorded the highest injury incidence; and
- The lower limb body region recorded the most days lost and had the highest mean days lost per injury.

Contribution to knowledge

The data pertaining to the physiological demands and incidence of injuries in women's rugby union remains limited. The finding in the literature review identified that there were no New Zealand based studies reporting on the incidence of injury in women's rugby union and no studies were conducted at the amateur level of participation. This was similar for the use of microtechnology in women's rugby union in New Zealand. Two published studies[25, 297] were identified prior to conducting the study in Chapter 2 and both of these were at an elite level of participation. However, since conducting the study in

Chapter 2, there has been one study[44] published reporting on the use of microtechnology in a provincial women's competition team in New Zealand.

Chapter 2: Movement demands and physiological responses.

To address research question 1, a prospective cohort descriptive study was undertaken to record the movement demands and physiological responses of 69 amateur women 15-a-side rugby union players, from the same team, over two consecutive years participating in a domestic level competition in New Zealand (Chapter 2). In conducting the study, players' HR were continuously monitored during match participation using a portable monitor (Team Heart Rate System, Polar, Kempele, Finland) and their movements were monitored using microtechnology GPS devices (OptimEye S5 device; Catapult Innovations, Melbourne, Australia), worn in a custom designed pocket, within a vest supplied by the device manufacturer, between the shoulder blades.

In comparing the relative distances in women's football (79.3 to 118.0 $m \cdot min^{-1}$: mean 101.0 ±11.9 $m \cdot min^{-1}$), hockey (79.0 to 115.0 $m \cdot min^{-1}$: mean: 98.5 ±15.6 $m \cdot min^{-1}$)[151] and rugby (54.8 to 68.0 $m \cdot min^{-1}$; mean: 61.4 ±9.3 $m \cdot min^{-1}$),[25, 44, 297] the relative distance per-match in the current study was less (38.3 ±13.7 $m \cdot min^{-1}$) by 38% (rugby) to 62% (football) of the relative distances covered per match. The differences between the current cohort and other studies indicated that the total and relative distances covered at the amateur club level were much lower and may be attributed to a difference in player fitness, playing style, match intensity, and player preparedness at the higher levels of participation.[165]

The finding that Forwards recorded a non-significantly higher maximum heart rate than Backs (191 $b^{\cdot}min^{-1}$ vs. 188 $b^{\cdot}min^{-1}$) was similar to previous studies.[60, 314] This finding was similar to male elite rugby union,[67] and a previous study[314] reporting on Canadian premier division women's club rugby (195 $b^{\cdot}min^{-1}$ vs. 192 $b^{\cdot}min^{-1}$), however the latter study only utilised four players per game, over ten matches. Further comparisons on women's rugby union were not able to be completed as other studies[25, 44] did not report HR as part of their analysis.

The results of this study suggested that the physical and physiological profile of the playing groups, at the amateur domestic level of women's rugby union, were quite similar and may be suggestive of generalised, rather than specialised, training regimes that may fail to prepare players for higher levels of competition. Amateur women's rugby union may benefit from the incorporation of positional specific training that would provide forward playing positions with the opportunity to develop collision and contact abilities, while concurrently allowing Backs a greater opportunity to train their high intensity running capacity. Further research is warranted to identify the training intensities of women rugby union players and to identify how the match demands can be incorporated into the training activities of women rugby union players.

Chapter 4: Training injury incidence in an amateur women's rugby union team in New Zealand over two consecutive seasons.

In Chapter 4, a descriptive, epidemiological observational study was conducted on a senior amateur women's rugby union team during the 2018 and 2019 competitions in New Zealand recording all the training injuries. A total of 69 players were enrolled in the study over the duration of the study, with data collection occurring from December to

August and competition matches occurring from March to August. There were three training sessions per week between December and February (preseason) and two training sessions a week for the duration of the competition season. The team enrolled in the study participated in a local domestic competition comprised of eight teams, in a two round home and away competition.

The team competed in a total of 114 training sessions over the duration of the study, resulting in an exposure of 3,339.5 training-hr. Individual player exposure times were recorded from whenever the player arrived at the training session through to the completion of that session. The data collection methodology was undertaken in accordance with the consensus statement on injury definitions and data collection procedures for studies in rugby union.[98]

The time-loss injury incidence (3.6 [95% CI: 2.0 to 6.3] per 1,000 training-hrs.) over the duration of the study were similar to the 2006 RWC(W) (3.0 [95% CI: 1.8 to 5.0] per 1,000 training-hrs.),[285] but slightly higher than the National[46] level (1.2 [95% CI: 0.4 to 3.1] per 1,000 practice-hrs). Similar to the different participation levels in male rugby union, the training injury incidence may be reflective of the level of playing standard.[261]

Forwards recorded a higher injury incidence for both the all-inclusive (7.5 [95% CI: 5.1 to 11.1] vs. 3.9 [95% CI: 2.3 to 6.7] per 1,000 training-hrs.) and time-loss (2.4 [95% CI: 1.2 to 4.8] vs. 1.2 [95% CI: 0.6 to 3.6] per 1,000 training-hrs.) injury definitions, compared with Backs (see Figures 5 & 6). However, as no studies reporting on women's rugby union training injuries provided player position information, comparisons were unable to be completed.

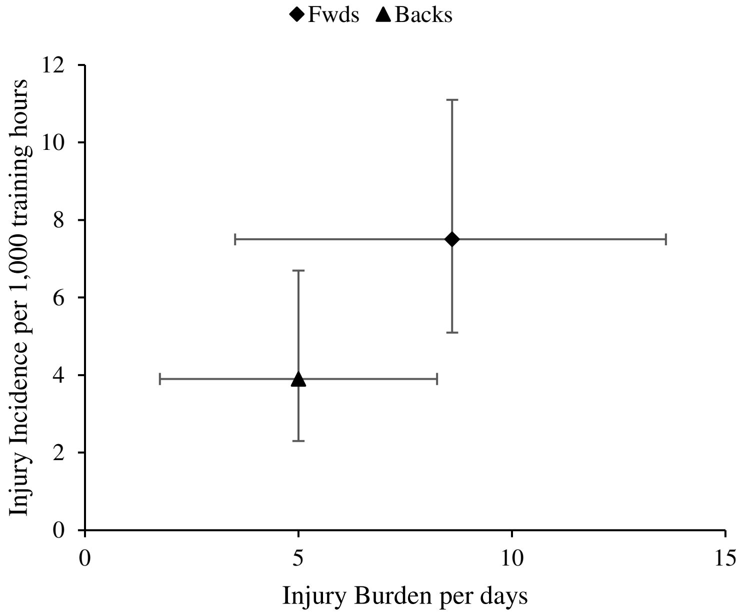

Figure 5: Injury incidence and injury burden for all training injuries with 95% Confidence Interval of amateur women's rugby union players in New Zealand by Forwards and Backs

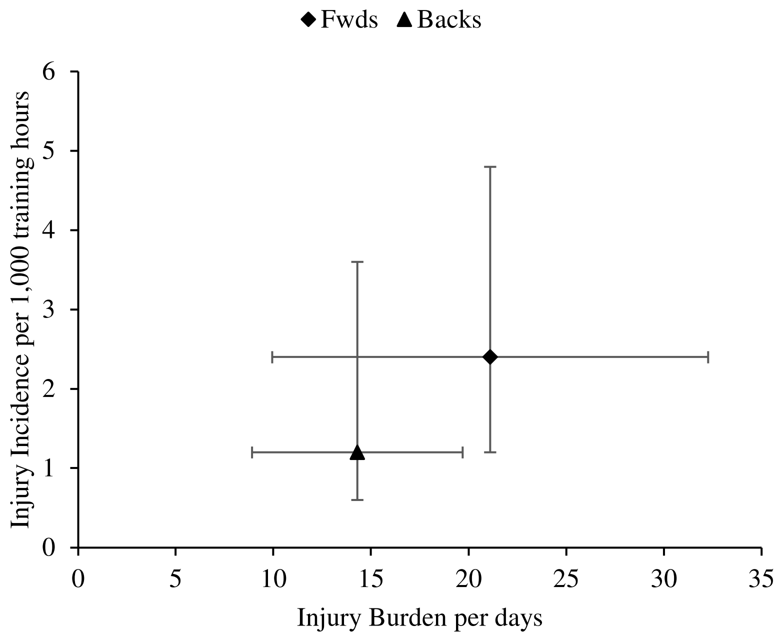

Figure 6: Injury incidence and injury burden of training injuries of time-loss injuries with 95% Confidence Interval for amateur women's rugby union players New Zealand by Forwards and Backs

The lower limb (consisting of the knee, lower leg, ankle, foot, and toes) was the most common injury location for both the all-encompassing (8.4 [95% CI: 5.8 to 12.1] per 1,000 training-hrs.) and time-loss (2.1 [95% CI: 1.0 to 4.4] per 1,000 training-hrs.) injury definitions (See Figures 7 & 8). However, when viewed by injury site, the ankle recorded the most all-encompassing (2.4 [95% CI: 1.2 to 4.8] per 1,000 training-hrs.) training injuries, while the knee and patella recorded the most time-loss (0.6 [95% CI: 0.1 to 2.4] per 1,000 training-hrs.) training injuries.

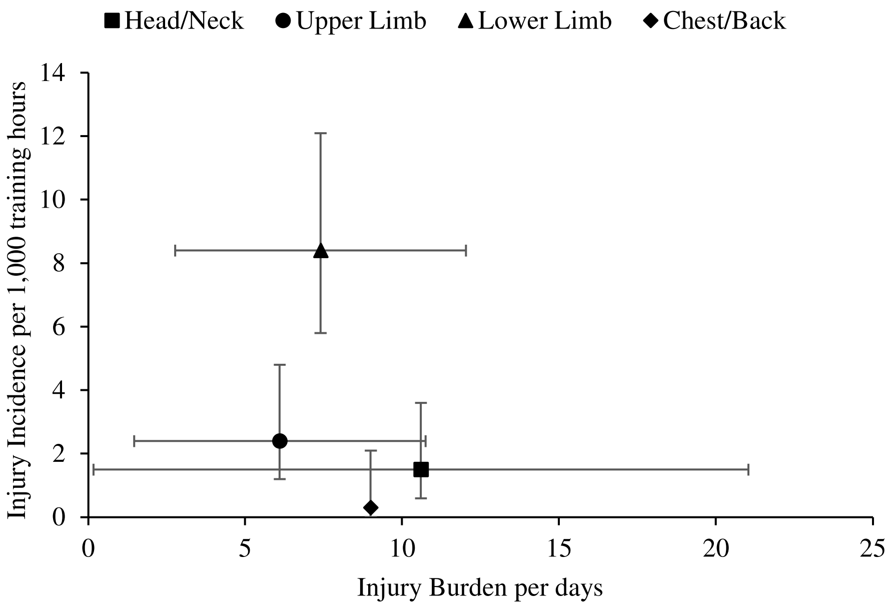

Figure 7: Incidence of injury and injury burden of all training injuries by anatomical region with 95% Confidence Interval for amateur women rugby union players in New Zealand

When combined, the tackle accounted for nearly a quarter (23.8%) of the total and time-loss (25.0%) injuries. The tackler accounted for more time-loss (16.7% vs. 8.3%) injuries than the ball-carrier and this may be indicative of their lack of skill when tackling or the effects of fatigue. More than half of total (54.8%) and time-loss (58.3%) training injuries occurred in the later stages of trainings. Previous studies that have reported training injuries in women's rugby union have not reported the training period, so no comparisons could be undertaken. Although all players were required to conduct a warm-up prior to commencing training, some players would arrive late due to work or family commitments and either do a jog around the training area or run straight into the training activity.

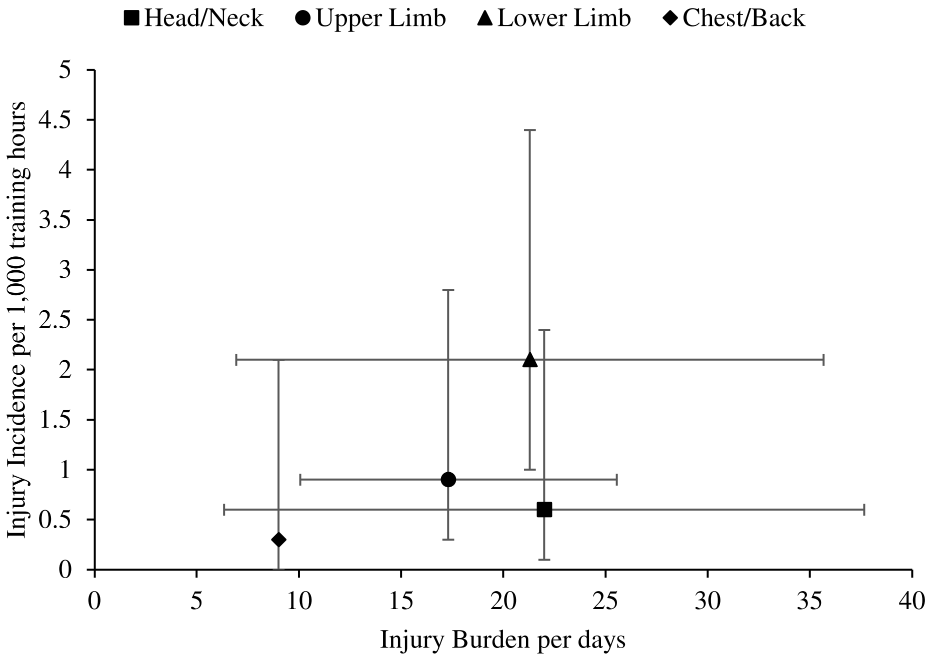

Figure 8: Incidence of injury and injury burden of time-loss training injuries by anatomical region with 95% Confidence Interval for amateur women rugby union players in New Zealand

The paucity of studies on women's rugby-15s training injuries was the catalyst for this study to report the incidence, site, type, and timing of injuries over two consecutive competition seasons of an amateur women's team in New Zealand. The findings indicate that training injuries occur most often to the lower limb and during the latter part of training sessions. These injuries are mostly minor in nature, resulting in minimal time-loss away from training. The time-loss training injury incidence in amateur women's rugby union in New Zealand was higher than that reported for national and international injury incidences.

Chapter 5: Match injury incidence in an amateur women's rugby union team in New Zealand over two consecutive seasons.

In Chapter 5, a descriptive, epidemiological observational study was conducted on a senior amateur women's rugby union team during the 2018 and 2019 competitions in New Zealand with all match related injuries recorded. A total of 69 players were enrolled in the study over the duration of the study, with data collection occurring from December to August and competition matches occurring from March to August.

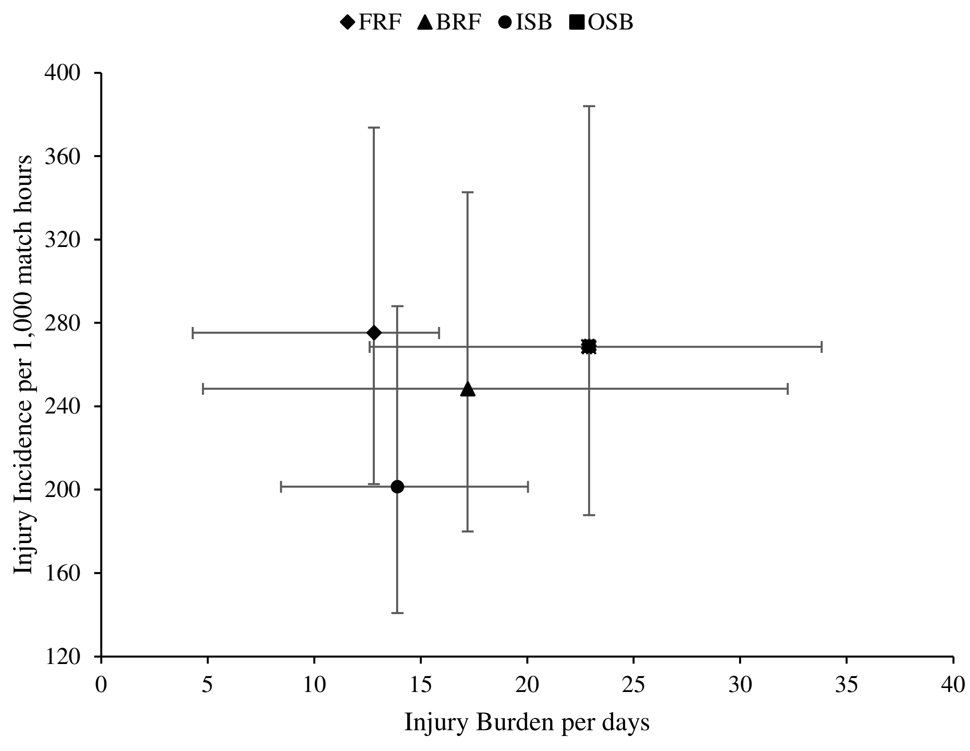

Figure 9: Injury incidence and injury burden of all match injuries with 95% Confidence Interval for amateur women's rugby union players in New Zealand by player group. FRF: Front-Row Forward; BRF: Back Row Forward; ISB: Inside Back; OSB: Outside Back

The team enrolled in the study participated in a local domestic competition comprised of eight teams, in a two round home and away competition. The team competed in a total of 28 matches over the duration of the study, resulting in a match exposure of 558.6 match-hr. The data collection methodology was undertaken in accordance with the consensus statement on injury definitions and data collection procedures for studies in rugby union.[98]

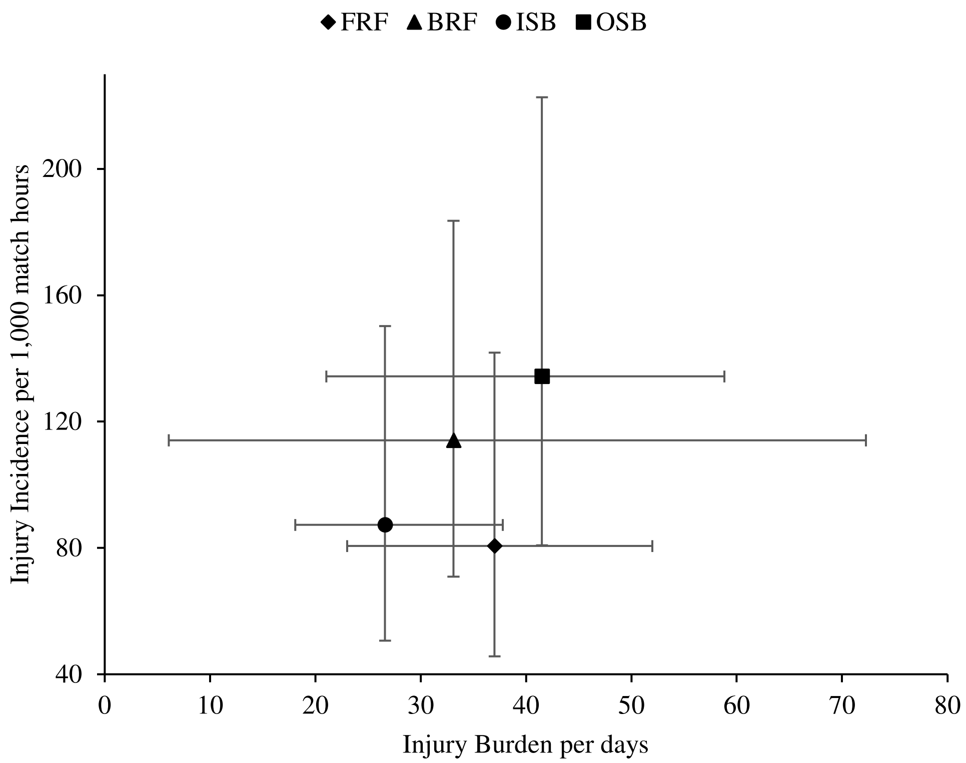

Figure 10: Injury incidence and injury burden of time-loss match injuries with 95% Confidence Interval injuries for amateur women's rugby union players in New Zealand by player group. FRF: Front-Row Forward; BRF: Back Row Forward; ISB: Inside Back; OSB: Outside Back

Both total and time-loss injury incidence recorded in this study were higher than professional men's rugby (81 [95% CI: 63 to 105] per 1,000 match-hrs.),[322] amateur men's rugby (46.0 [95% CI: 34.4 to 59.2] per 1,000 player hrs.),[332] and children and adolescent (26.7 [95% CI: 13.2 to 54.1] per 1,000 player-hr)[94] rugby injury-incidence. As can be seen by the comparisons between the current study and those reporting on the different levels of male rugby, the injury incidence of amateur women's rugby in New Zealand is more than double both total and time-loss injury incidence.

For total injuries, Forwards (261.8 [95% CI: 209.7 to 326.9] per 1,000 match-hrs.) recorded a higher total injury incidence when compared to Backs (230.2 [95% CI: 178.7 to 296.4] per 1,000 match-hrs.) (see Figure 9). However, for time-loss injuries, Backs (107.4 [95% CI: 74.2 to 155.6] per 1,000 match-hrs.) recorded a higher time-loss injury incidence when compared with Forwards (97.3 [95% CI: 67.6 to 140.1] per 1,000 match hrs) (see Figure 10). The finding that Forwards recorded more total injuries than Backs is similar to other studies[175, 285] reporting on women's rugby union. The finding that Backs recorded more time-loss injuries was not expected. A possible explanation for some of the findings recorded may be that some players competed with an injury that had not been appropriately managed.

Previous studies comparing injury incidence between male and female sports participants are contradictory, with some studies[88, 176, 213, 282, 300, 318, 336] reporting no meaningful differences, whereas other studies have reported meaningful differences.[5, 166, 212, 257, 260] Despite these findings, it has been identified that females report more specific injuries to areas such as the shoulder, knee, hip and ankle, as well as the number of concussions and Anterior Cruciate Ligament (ACL) injuries, when compared with males.[88, 176, 282, 300, 318, 336] Although there were several time-loss injuries to the knee, there were no ACL injuries, however there were a high number of medial and lateral collateral ligament strains and patella dislocation injuries, and this was unexpected.

There have been a variety of reasons suggested for the differences in the injury incidences between male and female sports participants. One aspect that has been suggested is the concept of toughness .[3, 220] Ignoring injuries and playing through pain is an expected norm for organised sports and conceptions of masculinity are reinforced by this behaviour.[3] Although some female sporting activities have also been portrayed as having a similar ethos of 'toughness'[220] it has also been identified[176] that injury reporting and safety behaviours are more normative in female organised sports, than of those seen in male organised sports, and this may account for the higher injury incidence that is reported. Another aspect for the differences in the injury incidence between male and female sports participants is the biologic explanation.[238] Anatomical,[141, 335] hormonal,[49, 160, 335] and biomechanical[141, 144] differences have been postulated as reasons for the differences in the injury incidence between male and female participants.

Females reportedly are smaller than their male counterparts, have weaker neck muscles, have a greater angular rotation and head-neck segment peak acceleration and displacement placing them at a higher risk of a sport-related concussion.[13, 304, 336] The hormonal changes that occur in women may result in low energy availability exposing them to an increased risk of injury.[207, 238, 259] This risk has been related to the effects of the menstrual cycle, different stages of the menstrual cycle and anatomical aspects.[293, 324, 325] This is reportedly similar for ligaments and tendons[324, 325] and may have been reflected in the findings of the high number of knee injuries recorded. However, no record of the menstrual cycle or oral contraceptive use was recorded during this study and future studies may consider including this aspect.

The incidence of concussion (16.1 [95% CI: 8.4 to 31.0] per 1,000 match-hrs.; (see Figure 11) over the study was higher than previous studies reporting on women's rugby union at the RWC(W) (3.5 [95% CI: 1.7 to 7.0] per 1,000 match hrs)[302] and collegiate rugby union (1.6 [95% CI:] per 1,000 player match-hrs.).[175] The mean time away from match activities for concussions was 28.9 ±3.7 days, which was similar to a previous study[168] where the majority of concussions took 28 days post-injury to recover. This was in conflict with the Concussion in Sport Consensus (CISC) where it was reported that 80% to 90% of all concussions recover in seven to 10 days.[223, 224]

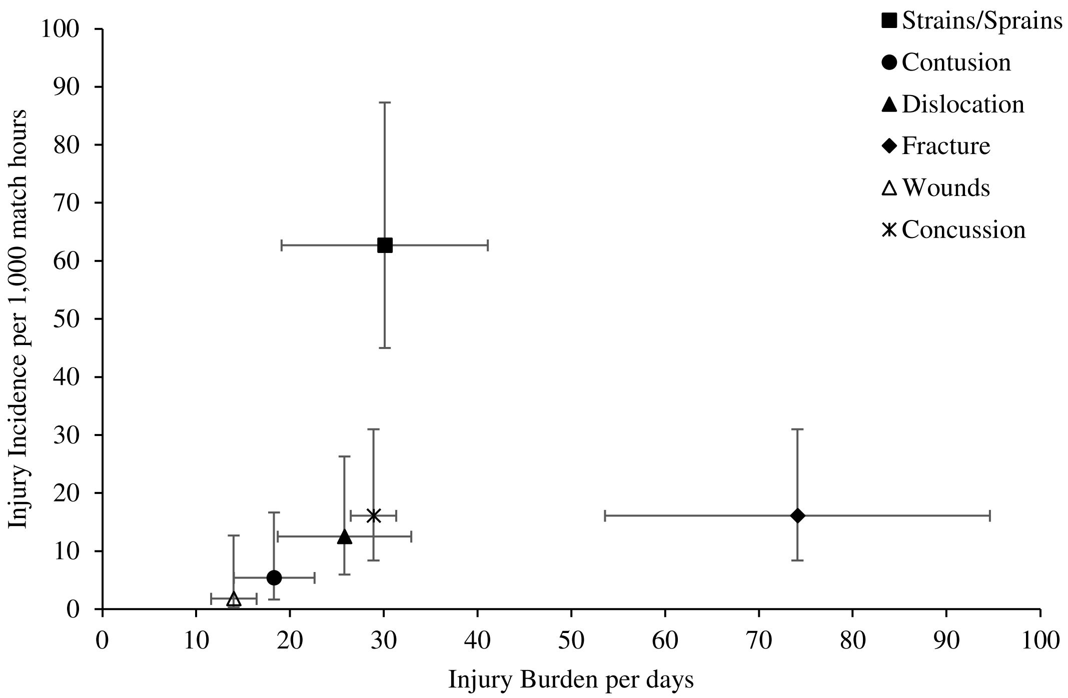

Figure 11: Injury incidence and injury burden with 95% Confidence Interval of time-loss match injuries by injury type for amateur women's rugby union players in New Zealand.

In regard to concussion severity, direct discussions with the national ruling body (New Zealand Rugby (NZR)) over the stand down requirements identified a possible conflict in how this is recorded. The mandatory stand down for a player with concussion, as directed by NZR, is 21 days and was calculated on the premise that the player was injured on the Saturday and missed two further Saturday matches and returned to full participation on the third Saturday (20 days after the injury) and this was to be recorded as 21 days' time lost. Yet in a recent International Olympic Committee consensus statement,[7] injury time lost was to be calculated "*from the day after the onset that the athlete is unable to participate through the day before the athlete is fully available for training and competition*". An example that was provided identified a player injured on a Monday and returning on the following Monday was counted as six (6) days' time loss (see Table 10, Bahr et al. 2020).[7] As a result, studies reporting a time loss of 21 days may be over-estimating this time-loss. The time loss reported for the participants enrolled in the series of studies in this thesis were calculated with the injury day being recorded as day '0', before recording time loss until the day before they participated in full match or training activities.

The prospective observational study outlined in Chapter 5 documented the incidence of match injuries occurring in an amateur women's rugby team over two consecutive domestic competition seasons. A consideration in the recording and reporting of the injuries in women's rugby union is that, typically, sports injury patterns have been presumed to be sport-specific not gender specific.[282] As well, males have traditionally been the visible participants in the majority of sporting activities and data pertaining to the types of equipment, training activities, sport-specific techniques, coaching styles, and injury management have been largely based on the male experiences. [282] This possibly places females at a higher risk of certain types of injuries, when compared with males.[5, 124] As reported in Chapter 5, the injury incidence of amateur women's rugby in New Zealand is more than double both the total and time-loss injury incidence of professional men's rugby,[322] amateur men's rugby,[332] and children and adolescent[94] rugby. The reason for this finding may be multifactorial and further research is warranted to identify the incidence of injuries. This study also highlights the need for injury prevention support for amateur women's rugby union teams in New Zealand.

Stress and Recovery

Not included in this thesis, but undertaken concurrently, the stress and recovery of women rugby union players was completed and retrospectively reviewed against all of the injuries that occurred.[201] The Recovery-Stress Questionnaire for Athletes (RESTQ-Sport),[169-171] a psychometrically paper-based questionnaire, was utilised to assess the players recovery-stress state and this was compiled for a group analysis. This identified some small differences in the groups stress-recovery state but, similar to previous studies,[139, 221] when reviewed on an individual basis there were more observable differences. The RESTQ-Sport 52 question was administered monthly over the duration of the competition with each assessment being undertaken two-days after the match played at the end of the calendar month. When data were reviewed as injured versus non-injured players, there were higher scale scores in some of the General Stress and Sport-Specific Stress sub-scales and lower scale scores in some of the General Recovery and Sport Specific Recovery scales. This is similar to previous studies[179, 289] and has been suggested that changes in these scales may be predictive of an injury and may assist with injury reduction and management.

Implications for coaches

As previously identified, the findings of this research show that, although players are participating in a senior women's rugby union competition, player experience ranged from no experience to a lot. The varying experience may be responsible for variations in skill level in aspects such as tackling, ball carrying, rucks, mauls, and scrummaging. Additionally, the wide range in experience and age (18 – 50 yrs.) may contribute to differences in player fitness and physiological capacity. This necessitates a different approach towards coaching women in rugby union, and in any sporting activity, when compared with males and should be considered when conducting any training activity. In particular, the findings of this thesis suggest that a women specific coaching programme should be implemented into RugbySmart and SmallBlacks coaching courses; this should consider both the physiological differences and the injury differences between male and female rugby participants. These aspects may include:

a. Differences in injury risk, injury type and injury severity of females when compared with males; and
b. The effects of the menstrual cycle on risk of injury, performance, and training availability; and
c. Biomechanical differences in women, when compared with men in aspects such as running, tackling, top speed, anthropometric aspects.

Future research should review and update the scientific literature relevant to coaching female rugby participants with the intention of incorporating and implementing the latest published research into all aspects of women's coaching.

Thesis limitations

The quality of the studies contained in this thesis were dependent on the data quality utilised for analysis.[132] This research was, epidemiologically, relatively small in cohort size and this is a major limitation to this study. As previously reported, there were 34 players enrolled in 2018 and 35 players enrolled in 2019. A total of 22 players were enrolled over the duration of the study. There was an average of a 36% loss of players over the duration of the study and this may have been reflective of the environment that the players were exposed to, the movement of the players to other clubs, and players returning to their home country having participated in the game for a season, as was the case with three of the players in this cohort. As a result of this, the findings reported in these studies may not be reflective of women's rugby union teams in other locations and further longitudinal research is warranted in order to establish the incidence of injuries and the movement demands of women rugby union players.

Chapter 2: Match participation and movement demands in amateur domestic women's rugby union in New Zealand**.**

There have been previous studies[25, 44, 297, 314] reporting on the physiological demands of women's rugby union but not all of these studies[314] have utilised microtechnology. Of the studies that have utilised microtechnology there were variations amongst these studies with:

(1) Different technological systems and sampling rates (5 Hz,[297] 10 Hz[25, 44]) utilised;
(2) The number of participants varied from eight players in a team[297] to premier[25] and provincial levels of participation;[44] and
(3) The number of matches varied with studies undertaken over one,[297] seven[44] and 14[25] matches.

As a result of these variations, the data should be interpreted with caution as there were several factors unique to this cohort that should be considered. These are:

(1) no study, to date, had utilised a single team over consecutive competition seasons and, as the team under investigation participated in the lower level of the local competition, the data may be lacking in transferability;

(2) In comparing the different studies, the different variables that were reported limits what can be utilised for inter-study comparisons. The use of variables that have been previously published for male-dominated sports, such as rugby union, may underestimate the physiological demands of women in this sporting environment.[53] For example:

    a. Of the published rugby-15's studies that were available prior to conducting this study, one study[314] utilised only four premier division club level players and analysed the data per-match utilising video analysis and heart-rate monitors, while another study[297] utilised a 5 Hz GPS device on eight players during a single women's national rugby union match. A third study[25] utilized a 10 Hz GPS for 129 games in the England women's premier division. More recently a study[44] reported the running demands of women's rugby union in New Zealand, covering seven matches of a provincial team, over one competition.

    b. All these studies reported calculations for absolute arbitrary speed zones that were utilised by Suarez-Arrones et al.[297] and based on thresholds by Cunniffe et al.[67] to allow for comparisons. These speed zones and thresholds have been previously established for male rugby participants.[298]

    c. Another aspect not reported in Chapter 3 is collision data. It has been reported[218] that the use of collision data enables the monitoring of these events and provides the ability to manipulate contact loads, provide comparisons for the physical and analytical components associated with collisions and provide for position specific collision conditioning programs. Although the GPS software produces this data, the accuracy of GPS collision data, such as collisions and tackles, for rugby union has been reported to be unclear[61, 114, 173, 278]Another consideration in reporting this data is that this is based upon male participants and may not be relevant to women rugby union players, given the different physical capabilities.[86]

Chapter 3: Match and training injuries in women's rugby union: A review of published studies.

Although there were a ten studies[19, 46, 57, 79, 101, 175, 217, 257, 285, 302] included, these varied by

(1) Methodological approach (i.e., retrospective[19, 57] and prospective[46, 79, 101, 175, 217, 257, 285, 302])

(2) Study length (i.e., one season,[19, 46, 79, 175] one tournament,[285, 302] through to five years[257]).

(3) Injury definition limiting the inter-study comparisons on some,[19, 57, 79, 257] but not all,[46, 101, 175, 217, 285, 302] of the identified studies.

(4) Reporting of injury exposure:

   a. Per 100 player games or practices,[19]
   b. Per 1,000 total (match and training combined) rugby-hr or athletic exposures (AE),[46, 57]
   c. Per 1,000 game-hr.[79, 101, 217, 257, 285, 302]

(5) Reporting of player position with some studies[19, 79, 175, 285, 302] providing player position, but only two studies[79, 175] reported specific player positions.

(6) Reporting of injury cause, [19, 46, 79, 257] injury type[19, 57] and match period.[79, 285, 302]

The publication of the 2007 consensus statement on injury definition and data collection procedures[98] for rugby union provided some standardisation for the reporting of rugby union injuries enabling a more uniform approach for some,[175, 217, 285, 302] but not all,[19, 46, 57, 79, 257] of the included studies. Although none of these studies complied with all of the reporting procedures outlined, they did utilize a variation of these procedures in terms of injury classification.

Chapter 4: Training injury incidence in an amateur women's rugby team in New Zealand over two consecutive seasons.

The findings of this study are limited to the training activities of a single amateur women's rugby union team over two consecutive domestic competition seasons. Although this is the first study to separately report on women's rugby union training injuries, the data should be interpreted with caution as there were several factors that should be considered. These are:

(1) There were several new players each season that had never participated in rugby union activities. It has been previously identified[215, 284, 310, 317] that inexperience of the athlete is a risk factor related to an injury occurring;

(2) Players were not individually coached at their level of understanding in the aspects of rugby union such as appropriate tackling skills, scrumming and rucks/mauls involvement;

(3) Coaches became visibly frustrated with the lack of skill and knowledge, and would coach the team at what appeared to be the level of male premier players, expecting players to undertake their own skill development outside of training;

(4) Not every player attended trainings from the beginning of the session and would join in without any form of warm-up. This is another risk factor for injuries occurring[215, 284, 310, 317]; and

(5) The women's team were often allocated the smallest area closest to the fence / trees and concrete path early on in the preseason competition until the teams were split to different training nights.

Chapter 5: Incidence of match injuries in an amateur women's rugby union team in New Zealand over two consecutive seasons.

The findings of this study are limited to a single amateur women's rugby union team over two consecutive domestic competition seasons. However, there are very few studies of women's rugby and the injuries sustained. The incidence of injuries may not be reflective of all amateur women's rugby union teams, given this was a small sample of New Zealand players. This may be in-part due to:

(1) The researcher working with the team under investigation has a special interest in sports medicine and injury prevention and therefore recorded all of the injuries seen;

(2) The team under investigation was the only team in the competition with a dedicated injury management specialist attached to the team;

(3) Several new players, with no previous rugby union experience, joined the team in both years of the study being conducted;

(4) The resources for injury management were limited and equipment normally utilised was often not available to the women participants; and

(5) The medical services provided to the male players were sometimes not available to the women participants, resulting in a delay in the diagnosis and treatment of the injuries that occurred.

In recording the training and match injuries in amateur women's rugby union (Chapter's 4 and 5), it is worth noting that the team involved in the study participated in the lower-level women's domestic rugby union competition. Although the competition was divided into two rounds, the first round saw all teams participate against each other, before the competition was divided into two divisions for the second round. The current cohort of players participated in the division two competition for the second round of each season, therefore the findings should be interpreted with caution as they may not reflect what happens at higher participation levels.

Considerations for women participants in research

It has recently been identified [86] that there are currently no scientific, evidence-based sport and exercise-related guidelines for training and nutrition that are customised for women participating in sporting activities. As a result, female-specific research is necessary as there is a risk that the true potential of women participating in sport will not occur if male-based research continues to be applied to females.

In conducting the studies in Chapters 4 and 5, it must be acknowledged that these studies did not record female-specific aspects such as use of oral contraceptives and the phase of the menstrual cycle when the injuries occurred.[78, 234] The effects of the cyclical variations in hormones, both positive and negative, on performance are clearly in need of further exploration. It has been identified[38, 188] that these aspects may be important for future research and should be considered in any further women's rugby union injury studies.

In addition, a list of considerations related to participant characteristics, selection criteria, experimental design, menstrual cycle phase definitions and general research considerations for women have been produced.[86] These aspects should be considered for inclusion into future studies on women's sports participation activities. Standardization of the methodological approaches and definitions will assist in producing the evidence-based guidelines necessary for the development of women specific sport and exercise-related guidelines for training and nutrition.

Breast injuries in contact sport

An aspect not considered in the current study, but recently highlighted, [28, 29, 291] that should be incorporated into future studies on women's rugby union are contact breast injuries. Contact breast injuries have been reported to affect 44% of female athletes involved in contact/combat sports, yet less than 10% of participants reported the injury to their coach or a health professional and even fewer (2%) received treatment.[28, 29, 291] Contact breast injuries have been identified to negatively affect the players performance in areas such as tackle making, contact initiation, running due to discomfort and decreased confidence.[29] A result of contact breast injuries can see complications such as fat necrosis develop and this can lead to persistent, and sometimes painful, masses in the breast.[219] Fat necrosis can also mimic the presentation of breast cancer.[219] As well, in pre-menarchal females, contact breast trauma can potentially lead to future breast asymmetries during development.[219] Incorporation of this injury into future research is warranted to determine the specific injury risk, mechanisms of this injury and to assist with the development of evidence-based strategies to prevent and manage these injuries in women rugby union players.

Future directions

This thesis reported on the physiological demands of participation in, and the injury epidemiology of training and match activities for amateur women's rugby union in New Zealand. As previously identified, although there are numerous studies reporting on rugby union match demands and injury epidemiology, these are primarily on male participants. Consequently, there is a paucity of available studies for women rugby union participants despite this being one of the biggest growth areas for rugby union worldwide. Women sports participants also present a unique set of characteristics different to male sports participants and there is a need for research to be undertaken in order for women specific data to be available.[65, 87] To achieve this in rugby union, future research should focus on:

(1) The establishment of GPS related reportable variables specific to women's rugby union. This may include;
   a. Kinematic variables thresholds; and
   b. Reporting positional groups;

(2) The identification of women specific injury risk factors through ongoing epidemiological studies focusing on both training and match injuries at all levels of participation. This may need to include:
   a. The establishment of, and access to, an electronic database for the reporting of women's rugby union training and match injuries; and
   b. Identification of the key reporting variables for the recording of injuries in women's rugby union;

c. Impact of hormones on the incidence of injuries in women's rugby union players with specific focus on:
    i. Lower limb injuries;
    ii. Mild Traumatic Brain Injury (mTBI); and
    iii. Duration of recovery from match and training injuries
d. The use of breast guards for the prevention of injuries to the breast;

(3) The development of injury prevention strategies specific to women's rugby union participants. This may include:
   a. Review of current available injury prevention resources (i.e., FIFA 11+; RugbySmart) for adaption to women specific activities; and
   b. Review of rugby union coaching resources such as RugbySmart and SmallBlacks, to include women specific training activities;

(4) Implementation of a monitoring system of players for injuries that occur in women's rugby union in order to identify any potential long-term consequences from rugby union match and training participation (e.g. osteoarthritis, joint and back pain, depression, chronic musculoskeletal injuries).[145] Future player welfare studies may consider undertaking either a women specific or a comparison model for the long-term effects of rugby union participation.

Although the studies contained within this thesis record and report on training and match injuries in women's rugby union, this was only available with the researcher embedded into the team as part of the coaching and management role. As has been identified previously, the researcher was the only medical provider present at games and often teams participated without any form of medical support. In regard to recommendations 2 and 4, the quality of the research undertaken, and the recording and reporting of the injuries that occur for women rugby union players will depend on the data provided.[129] To enable this to occur the possible solutions for this may be:

i. The establishment of a central database for the collection of sports injury data accessible by identified personnel trained to record the data, that are based within every team at all levels of participation. This may be through a University or other organisation provided with the support to conduct ongoing research and evaluation of the injuries that are recorded and the ability to provide timely reports and updates on these injuries; and

ii. The implementation by New Zealand Rugby for the requirement that every team participating in rugby union are to have a qualified sports medic embedded with the team. The requirement of a "No medic – No play" rule ensures that irrespective of the activity, there is medical support there. This sports medic training is currently available through Sports Medicine New Zealand as a series of short courses culminating in a qualification with a requirement of a two-yearly revision process. This training can also incorporate training for the recording and reporting of all injuries that occur, and these should be recorded on a database managed through a central location.

Another possible database source that can be utilised to report on the injuries that occur to women rugby union players is through the Accident Compensations Corporation (ACC) database. New Zealand is in the unique position where they have a no-fault levy- and taxpayer-funded injury insurance and rehabilitation scheme enacted by statue and administered by ACC.[128] The ACC collects and stores information about all injuries that are reported in New Zealand that results in claims against the scheme, providing a nationwide all activity injury surveillance system. 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. However, ACC does not monitor activity exposure, and this can limit the information available.

Several studies have been conducted utilising the information in the ACC database and have reported on rugby union,[131, 133, 134, 159, 198, 199, 262, 263] rugby league,[189, 190, 193-195, 199, 216] cricket,[159, 199] netball,[159, 199, 272] football,[199] sports-related concussion,[128, 183] traumatic brain injuries,[200] dental injuries[214, 319] and the effects of injury prevention strategies.[128-130, 132-134] More recently data from ACC has been combined with the recorded player numbers for rugby union that is held by New Zealand Rugby (NZR) that provided a study reporting on the risks faced by community rugby union players in New Zealand.[264] This combination of information held by NZR and ACC's databases can provide another source for the reporting of the injuries that occur in women's rugby union. However, this data needs to be produced annually to enable the identification of the risks involved and, therefore, access to the ACC database combined with the player base numbers held by NZR needs to be available to the organisation that takes responsibility for the production of these reports.

Conclusions

Rugby union is a physically demanding collision and contact sport that is increasing in popularity with women participants. Previous research in rugby union match demands and injury epidemiology has been undertaken primarily using male participants. As such, the currently available data on these aspects do not provide an accurate representation of the match demands and injury risk present in women's rugby union. The aim of this thesis was therefore to provide a more accurate representation of the match demands and injury epidemiology of 15-a-side amateur women's rugby union participants in New Zealand.

By undertaking a prospective observational approach, over two consecutive years, through the use of microtechnology, injury surveillance and data collection, the areas of concern in terms of training methodologies, vulnerable body regions/structures, injury management and rehabilitation limitations have been highlighted. This information can be utilised in order to develop injury prevention strategies, training methodologies and resource identification specific to women's rugby union.

Finally, with the recent publications reporting on the Team-sport Injury Prevention (TIP)[246] cycle and the guidelines for community-based injury surveillance in rugby union,[37] there is a structure available for the recording and reporting of injuries at all levels of women's rugby union participation. Future research on women's rugby union activities utilising the TIP[246] and community-based guidelines[37] need to be undertaken in order to evaluate the effectiveness of injury prevention interventions and/or any changes in the rules and regulations governing women's rugby union that are implemented.

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Appendices to Thesis

Appendix I: Medical History Questionnaire

Women's Rugby Union Research Medical Questionnaire

1) To download the Information Sheet pertaining to the research being undertaken please read the Women's Rugby Union Research Participation Information Sheet [link attached]

By clicking 'YES' you are giving agreeing that:

That you are giving consent to participate in the research and:

- I have read and understood the information provided about this research project in the Information Sheet dated 12th August 2017;
- I certify that I do not have a history of epilepsy, seizure disorders, clinical photosensitivity, or flitter vertigo;
- I have had an opportunity to ask questions and to have them answered;
- I agree to participate in the research;
- I understand that taking part in this study is voluntary (my choice) and 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;
- I understand that in the event of a medical situation the information obtained as part of this research project may be used to assist in my medical care and that my identified legal guardian, next-of-kin or parent will be informed of the situation;
- I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

I have read and understood the Explanatory Statement and am happy to participate in the research. *(If you answer no to this question, you will be unable to participate in the research. This does not affect your participation in the team or team related activities for the competition season)*

( ) Yes; ( ) No

Player Demographics

2) Please insert your full name ____

3) Please enter your date of birth (DD/MM/YYYY) _________________________________

4) Please indicate your height in cms
( ) 150 cms; ( ) 151 cms; ( ) 152 cms ……. ( ) >200 cms

5) Please indicate your weight (bony mass) in kgs?
( ) < 50 kgs; ( ) 50 kgs; ( ) 51 kgs ……. ( ) > 130 kgs

6) What position do you primarily play in rugby union?
( ) Prop; ( ) Hooker; ( ) Lock; ;( ) Flanker; ( ) No. 8; ( ) Half-Back; ( ) 1st 5/8; ( ) 2nd 5/8; ( ) Centre; ( ) Wing ( ) Fullback

Past Medical History

7) Have you ever had, or do you now have and of the following:

	Yes	No
Head injury	( )	( )
Epilepsy / Seizures	( )	( )
Faints, Fits or 'Funny Turns	( )	( )
Brain Injuries (not concussion)	( )	( )
Brain Surgery	( )	( )
Clinical Photosensitivity	( )	( )
Flutter Vertigo	( )	( )
Neck/Back disorders	( )	( )
Eye problems	( )	( )
Glasses / Contacts	( )	( )
Nose Bleeds	( )	( )
Dental problems	( )	( )
Deafness/Ear problems	( )	( )
Asthma	( )	( )

	Yes	No
Bronchitis	( )	( )
Chest Pains	( )	( )
Infectious Diseases	( )	( )
Heart Problems	( )	( )
Ulcers	( )	( )
Bowel problems	( )	( )
Urinary Infections	( )	( )
Kidney problems	( )	( )
Diabetes	( )	( )
Blood Transfusions	( )	( )
Hepatitis	( )	( )
Glandular Fever	( )	( )
Thyroid Disorder	( )	( )
Rheumatic Fever	( )	( )

8) Have you ever had a concussion

( ) Yes ( ) No

9) If yes you have had a concussion, how many in the previous six months**?** ____________________

10) How many concussions have you had in the previous two (2) years?________________________

11) If you answered yes to having had a concussion can you please indicate

	0	**1**	**2**	**3-4**	**5-9**	**10-19**	**20+**	**Don't know, but more than 3**
How many concussions did you sustain?	( )	( )	( )	( )	( )	( )	( )	( )
Number of times you were evaluated by a health professional	( )	( )	( )	( )	( )	( )	( )	( )
Number of times you had memory loss	( )	( )	( )	( )	( )	( )	( )	( )
Number of times you had prolonged symptoms (more than 4 weeks)	( )	( )	( )	( )	( )	( )	( )	( )
Number of times you returned to the activity the same day after losing consciousness	( )	( )	( )	( )	( )	( )	( )	( )
Number of times you reported your concussion	( )	( )	( )	( )	( )	( )	( )	( )

12) As a result of any concussion / head injury that you had:

	Yes	No	Don't know
Have you ever been diagnosed with Post-Concussion Syndrome	( )	( )	( )
Have you ever been diagnosed with depression since having had a concussion	( )	( )	( )
Have you ever contemplated, or attempted, suicide since having had a concussion	( )	( )	( )
Do you currently suffer from Post-Concussion Syndrome	( )	( )	( )
Do you experience regular bouts of headaches	( )	( )	( )
Do you think the concussions you sustained have had a permanent effect on your memory or thinking skills as you have got older	( )	( )	( )
Have you been told by a health practitioner that your memory or thinking skills have deteriorated as a result of a concussion (s) sustained while playing rugby union	( )	( )	( )

13) Have you had any previous Fractures / Broken Bones?
( ) Yes ( ) No

14) Please list the fractures / broken bones you have had ____________________________________

15) Have you had any previous Sprains / Strains?
( ) Yes ( ) No

16) Please list the body parts for the sprains and strains ______________________________________

17) Please list any regular medications that you are currently taking (i.e., for Asthma, Diabetes) - No need to list the oral contraceptive pill ____

18) Do you have any allergies to medications or foods?
( ) Yes ( ) No

19) If yes, what medications or foods are you allergic to and what reaction do you have (i.e., rash, anaphylactic etc.)_____________________________

20) Do you wear any body protection equipment

	Yes	No
Headgear	( )	( )
Mouthguard	( )	( )
Body Armour	( )	( )

Rivermead 22

21) The questionnaire consists of a series of statements. Please select the answer that most accurately reflects how you feel since your last match. For each statement there are seven possible answers.

0 = None at all; **1** = Slightly; **2** = Sometimes; **3** = Often; **4** = More Often;
5 = Very Often; **6** = All the time

Please make your selection by marking the number corresponding to the appropriate answer.

	0	**1**	**2**	**3**	**4**	**5**	**6**
1. Headache	( )	( )	( )	( )	( )	( )	( )
2. "Pressure in the head"	( )	( )	( )	( )	( )	( )	( )
3. Neck Pain	( )	( )	( )	( )	( )	( )	( )
4. Nausea or Vomiting	( )	( )	( )	( )	( )	( )	( )
5. Dizziness	( )	( )	( )	( )	( )	( )	( )
6. Blurred Vision	( )	( )	( )	( )	( )	( )	( )
7. Balance Problems	( )	( )	( )	( )	( )	( )	( )
8. Sensitivity to light	( )	( )	( )	( )	( )	( )	( )
9. Sensitivity to noise	( )	( )	( )	( )	( )	( )	( )
10. Feeling slowed down	( )	( )	( )	( )	( )	( )	( )
11. Feeling like "in a fog"	( )	( )	( )	( )	( )	( )	( )
12. "Don't feel right"	( )	( )	( )	( )	( )	( )	( )
13. Difficulty Concentrating	( )	( )	( )	( )	( )	( )	( )
14. Difficulty remembering	( )	( )	( )	( )	( )	( )	( )
15. Fatigue or low energy	( )	( )	( )	( )	( )	( )	( )
16. Confusion	( )	( )	( )	( )	( )	( )	( )
17. Drowsiness	( )	( )	( )	( )	( )	( )	( )
18. Trouble falling asleep	( )	( )	( )	( )	( )	( )	( )
19. More emotional	( )	( )	( )	( )	( )	( )	( )
20. Irritability	( )	( )	( )	( )	( )	( )	( )
21. Sadness	( )	( )	( )	( )	( )	( )	( )
22. Nervous or Anxious	( )	( )	( )	( )	( )	( )	( )

22) Thank you for completing the questionnaire

Appendix II: Injury Reporting Form

Women's Rugby Union Player Injury Report Form

Incident Details

Date: __ __ / __ __ / __ __ **Time** __ __ : __ __

Location:

Patient Details

Surname

First

Address

Phone: **(M)** 0 -

(H) 0 -

Date of Birth / / **Age**

History

Primary Survey

Response	**Airway**	**Breathing**	**Circulation**
Awake	Clear	Normal	Normal
Voice	Obstructed	Shallow	Pale
Pain		Agonal	Flushed
Unresponsive		Absent	Cyanosed

External Bleeding **Yes** **No**

Possibility of unconsciousness **Yes** **No**

Initial Assessment

Treatment

Drug	**Dose**	**Time**	**Sign**

Disposal

Return	Hospital	Ambulance	Other
Sat out	Physio	Review later	

Transportation

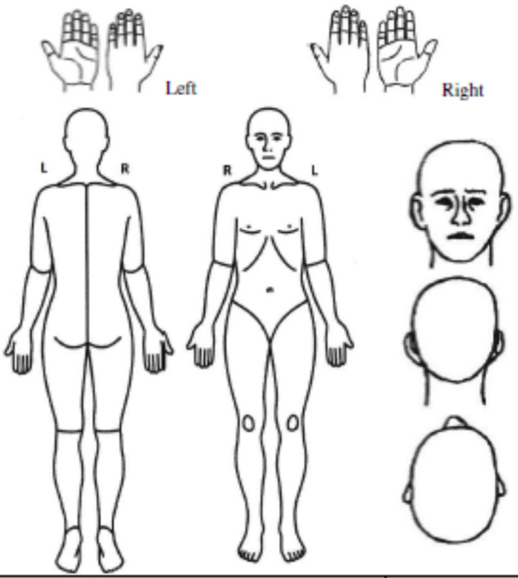
Own · Ambulance · Other

Medic/s

Observations / Findings

B - Bleeding **D** - Dislocation **S** - Swelling **W** - Wound

C - Contusion **F** - Fracture **P** - Pain **L** - Laceration



Observations

Time				
AVPU				
Resp				
Pulse				
BP				
Glasgow Coma Scale				
Eye	/4	/4	/4	/4
Voice	/5	/5	/5	/5
Motor	/6	/6	/6	/6
Score	**/15**	**/15**	**/15**	**/15**

Pupils	Left	Right	Left	Right	Left	Right	Left	Right
Reactive								
Size mm								

• 1 mm ● 2 mm ● 3 mm ● 4 mm ● 5 mm ● 6 mm ● 7 mm ● 8 mm

Cervical Spine precautions

C-Spine tenderness Yes ☐ No ☐

Alt sensation Upper Limbs ☐ Lower Limbs ☐

Collar Applied (Time)

Glasgow Coma Scale

Eye Opening		**Voice Response**		**Motor Response**	
None	1	None	1	None	1
Pain	2	Incomprehensible sounds	2	Extension posturing	2
Loud Voice	3	Incomprehensible words	3	Flexion posturing	3
Spontaneous	4	Confused	4	Withdrawal	4
		Orientated	5	Localises	5
				Obeys	6

Appendix III: Institutional Ethics Approval

Due to COVID-19, it was decided to utilise data collected prior to the commencement of the Doctor of Philosophy as part of the data collection. The data collected prior to 2019 was collected under the AUTEC (16/35) ethics application. Upon commencing the Doctor of Philosophy, ethics was applied for through the Health and Disability Ethics Committee (HDEC 18/STH/224). This was further amended in April 2019.

AUT
TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

21 February 2019

Patria Hume
Faculty of Health and Environmental Sciences

Dear Patria

Ethics Application: **16/35 Impact forces associated with match participation in amateur women's netball, soccer and rugby league and the identification of sport-related concussion.**

At their meeting of 11 February 2019, the Auckland University of Technology Ethics Committee (AUTEC) received the report on your ethics application. AUTEC noted your report and asked me to thank you.

On behalf of AUTEC, I congratulate the researchers on the successful completion of the 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 me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 6038.

Yours sincerely

K O'Connor

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: Doug King

Health and Disability Ethics Committees

Health and Disability Ethics Committees
Ministry of Health
133 Molesworth Street
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdecs@moh.govt.nz

09 April 2019

Dr Doug King
137 Whites Line East
Waiwhetu
Lower Hutt 5010

Dear Dr King

Re:	**Ethics ref:**	**18/STH/224/AM01**
	Study title:	Injury incidence, physiological demands, stress and recovery changes and the management of concussion in amateur women's rugby union in New Zealand

I am pleased to advise that this amendment has been *approved* by the Southern Health and Disability Ethics Committee. This decision was made through the HDEC Expedited Review pathway.

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,

Ms Raewyn Idoine
Chairperson
Southern Health and Disability Ethics Committee

Appendix IV: Sample of a participant information sheet and consent form

PARTICIPANT INFORMATION SHEET

Study title:	**Injuries in amateur women's rugby union in New Zealand**		
Locality:	**Lower Hutt, New Zealand**	Ethics committee ref.:	**18/STH/224**
Lead investigator:	**Dr Doug King**	Contact phone number:	**+64 22 034 1580**

You are invited to take part in a study on the injuries in women's rugby union in New Zealand. Whether or not you take part is your choice. If you do not want to take part, you do not have to give a reason, and it will not affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you would like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this information with you and answer any questions you may have. You do not have to decide today whether you will participate in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

If you agree to take part in this study, you will be asked to sign the Consent Form on the last page of this document. You will be given a copy of both the Participant Information Sheet and the Consent Form to keep.

This document is [*x*] pages long, including the Consent Form. Please make sure you have read and understood all the pages.

What is the purpose of the study?

The purpose of the study is to monitor and record the demands of, and the injuries that occur from participating in match and training activities of amateur women's rugby union in New Zealand.

It is envisaged that the information obtained by this study will assist with the development of injury prevention strategies for women participating in rugby union activities, add to the world-wide scientific information on women's rugby union participants and assist in the development of women specific injury management protocols.

The study has been reviewed and approved by the Health and Disability Ethics Committee.

What will my participation in the study involve?

You have been chosen to participate in this study as you are a member of the Hutt Old Boys Marist Women's rugby union team. The activities undertaken in this study are no different from the activities you normally take for participating in rugby union activities or the rehabilitation of those injuries that occur from women's rugby union activities but will enable to collection of the information for scientific purposes.

The study will involve you being asked to complete an online health questionnaire and a Recovery and Stress Questionnaire Sport (RESTQ-Sport), a baseline King-Devick reading test with an eye tracker on a laptop and a Sports Concussion Assessment Tool 5th edition (SCAT5). These baseline tests will be used to evaluate you against in the event of a suspected concussion occurring during training or matches. This information will be collected at the beginning of your enrolment in the study.

Your medial history questionnaire will be retained by the team medic in order to provide any relevant information to immediate response personnel if you are injured. The information on your medical health questionnaire will also be included in the research but this will be de-identifed. Your previous concussion history will also be recorded and this will be used as part of the analysis of the data obtained. This de-identified history will be recorded in a database only accessable to the investigators directly involved in the study.

In the preseason you will be asked to undertake a series of physical assessments such as a 40 metre sprint, an aerobic fitness test (Yo-Yo Test) and an anaerobic fitness test (the Repeat High Intensity Endurance Test – RHIET). This will be repeated mid season during the competition break before starting the second round of the Wellington women's rugby union competitions

During the competition season you will be asked to complete a 6-question short form evaluation of your recovery (RecoveryCue) on each week before the first training session following a competition match, and the RESTQ-Sport every two (2) weeks as part of the ongoing monitoring of you.

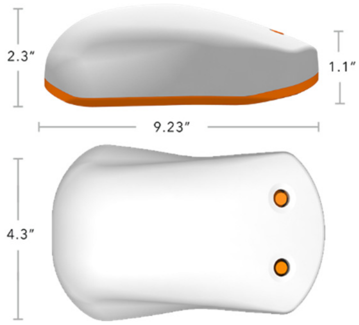
Should an injury occur during match or training participation, this will be recorded and you will be referred to the appropriate healthcare practitioner for further assessment and management as appropriate for the injury sustained.

You will be asked to wear a Global Positioning System (GPS) (see below) tracker and a heart rate monitor (HRM) which will be located in a harness you wear over your upper chest during every competition match and at all training sessions. The GPS and HRM data will be downloaded after the match or training activity and reported back to the team as summary information.

The Catapult OptimEye S5 Athletic Tracking Unit GPS that will be placed in the tight fitting vest worn on your upper chest and the GPS will be located between your shoulder blades during match participation enabling tracking of acceleration, deceleration, linear motion and impact forces in real time. The information from this device will be downloaded for further analysis

Following every competition match you may be asked to complete the King-Devick reading test on an iPad. For those players with a suspected concussion you will be asked to complete the King-Devick test, and should a concussion be identified you will be asked to undertake a further assessment as outlined below. You will also be asked to undertake a eye screening test using the RETeval electroretinogram (ERG) test. This involves the use of a hand-held monitor to measure pupil response to lights that will flash for approximately 30 seconds per eye. This will occur after the King-Devick test is completed.

Should you be identified as having incurred a concussive injury, you will be asked to complete the SCAT5 and further assessments with the King-Devick test on the laptop with the eye tracker and an assessment with a tactile stimulation of your fingers (Brain Gauge) (see below). The results of the SCAT5 will be provided to you to take to a health practitioner for their evaluation as part of their assessment. If, as a result of this assessment, a concussion is diagnosed then you will be required to complete the required stand-down period as stipulated by New Zealand Rugby Union and the Accident Compensation Corporation national Guideline for Sport Concussion in New Zealand. This includes, but is not limited to a period of cognitive rest, graduated return to activity and, will require a further health practitioner assessment and medical clearance before being allowed to return to your sporting activities.



The 'Brain Gauge' vibro-tactile stimulation hand held device is the same shape and size to that of a standard computer mouse. Sitting at a computer and when your logged into the Cortical metrics program you will be guided through a series of test. The two dots on the top of the mouse will vibrate and the computer program will advise you of what actions to take

During the period of concussion recovery and graduated return to activity, you will be asked to complete a series of assessments with the RESTQ-Sport and on the King-Devick eye-tracker and Brain Gauge to monitor your progress. The results of these assessments will be provided to you as to feedback to how you are recovering. A copy of these results can be provided to you for your health practitioner if you require this.

The study duration will be the competition duration of the Wellington women's rugby union domestic competitions throughout 2019-2021. Match and training activities will be studied over this period.

Participating in this research project will not cost you apart from your time that you normally provide for participating in the 2019-2021 Wellington women's rugby union domestic competitions. You will be asked to attend one training session where the fitness tests will be undertaken. In addition, you will be asked to give approximately 15 minutes for a baseline King-Devick test on a laptop with an eye tracker, 15 minutes for a baseline SCAT5 and five minutes post-match for a follow-up K-D test on an iPad. If you are identified as having a concussion, or possible concussive injury a repeat SCAT5 will be completed requiring approximately 15 to 20 minutes, a repeat King-Devick test on the laptop with the eye tracker and 20 minutes for the Brain Gauge.

What are the possible benefits and risks of this study?

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 in particular women's rugby union domestic competitions.

Only those discomforts and risks that normally occur from participating in Wellington women's rugby union domestic competitions match and training activities. This includes the risk of a sports-related concussion. This risk can be increased if you have had a previous concussion.

The medical care of all participants will be the same for both enrolled and non-enrolled participants in this study.

Who pays for the study?

There are no financial costs to you for participating in this study. The study is being undertaken as part of the university qualification of a Doctor of Philosophy that Dr. Doug King is undertaking, and the costs of the equipment are through the University.

What if something goes wrong?

If you were injured in this study, you would be eligible **to apply** for compensation from ACC just as you would be if you were injured in an accident at work or at home. This does not mean that your claim will automatically be accepted. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your recovery.

If you have private health or life insurance, you may wish to check with your insurer that taking part in this study will not affect your cover.

What are my rights?

Your participation in this research is voluntary. You are free to withdraw consent and discontinue participation from the study at any time before the completion of the 2021 Wellington women's rugby union domestic competition without influencing any present and/or future involvement with Massey University or with the team.

You may ask for a copy of your results at any time, and you have the option of requesting a report of the research outcomes at the completion of the study. You have the right to access your information collected on you and you can amend any information that is collected.

You may withdraw from the study at any time without there being any adverse consequences of any kind. If you chose to withdraw from the research, you have the right to have your data withdrawn from the study.

In the case of you recording a concussion through the course of your sporting activities, the team coach and manager will be advised that you have been injured and will be medically stood down until cleared by a health practitioner.

The medical care of you as a member of the Hutt Old Boys Marist Women's rugby union team is paramount. Your participation in this research project will not alter how your injuries are managed nor influence the medical care decisions made. Your personal health comes before the research data.

What happens after the study or if I change my mind?

The study is focused on monitoring you during your participation in rugby union activities as a member of the Hutt Old Boys Marist women's rugby union team. The data obtained will be stored for a minimum of six (6) years from the completion of the study and will not be utilised for any other future use. The data from this research project will be coded and held de-identified in secure storage at the School of Sport, Exercise and Nutrition at Massey University (Palmerston North) under the responsibility of the principal investigator of the study in accordance with the requirements of the New Zealand Privacy Act (1993).

All references to participants will be by a code number only in terms of the research project and publications. Identification information will be stored on a separate file and computer from that containing the actual data only available to Dr Doug King.

Only the investigators will have access to de-identified computerised data obtained from the participants in the Hutt Old Boys Marist women's rugby union domestic team.

Upon completion of the study, the findings will be incorporated into the Doctor of Philosophy thesis that Dr King is undertaking. This thesis will consist of a series of articles that will have been submitted for publication in peer-reviewed scientific journals that are a result of the data collected through this research project. Some of the data obtained may be presented at international sports-medicine conferences.

A summary of each aspect of the research project will be available within six (6) months of the completion of the research project and this will be available for every participant and to the club. No personal identifying information will be provided in these publications or the summaries.

Who do I contact for more information or if I have concerns?

If you have any questions, concerns or complaints about the study at any stage, you can contact:

Researchers Contact Details:

Dr Doug King, School of Sport, Exercise and Nutrition, Massey University. Email: doug.king35@gmail.com or phone +64 22 034 1580.

Project Supervisor Contact Details

Dr Matt Barnes, School of Sport, Exercise and Nutrition, Massey University. Email: M.Barnes@massey.ac.nz or phone +64 6 356 9099 ext. 83822.

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone:	0800 555 050
Fax:	0800 2 SUPPORT (0800 2787 7678)
Email:	advocacy@hdc.org.nz

For Maori Heath support please contact :

Name:	Dr Trevor Clark
Phone:	+61 416 874 168
Email:	trev.waves@yahoo.com.au / tclark@acpe.edu.au

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone:	0800 4 ETHICS
Email:	hdecs@moh.govt.nz

CONSENT FORM

Injuries in amateur women's rugby union in New Zealand

Please tick to indicate you consent to the following

I have read or have had read to me in my first language, and I understand the Participant Information Sheet.		
I have been given sufficient time to consider whether or not to participate in this study.		
I have had the opportunity to use a legal representative, whanau/ family support or a friend to help me ask questions and understand the study.		
I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.		
I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without this affecting my medical care.		
I consent to the research staff collecting and processing my information, including information about my health.		
If I decide to withdraw from the study, I agree that the information collected about me up to the point when I withdraw may continue to be processed.	Yes ☐	No ☐
I consent to my GP or current provider being informed about my participation in the study and of any significant abnormal results obtained during the study.	Yes ☐	No ☐
I agree to an approved auditor appointed by the New Zealand Health and Disability Ethic Committees, or any relevant regulatory authority or their approved representative reviewing my relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.		
I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study.		

I understand the compensation provisions in case of injury during the study.		
I know who to contact if I have any questions about the study in general.		
I understand my responsibilities as a study participant.		
I wish to receive a summary of the results from the study.	Yes ☐	No ☐

Declaration by participant:

I hereby consent to take part in this study.

Participant's name:	
Signature:	Date:

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant and have answered the participant's questions about it.

I believe that the participant understands the study and has given informed consent to participate.

Researcher's name:	
Signature:	Date: