CHAPTER ONE

INTRODUCTION

Risk management in sport

Almost all physical and sporting activities carry inherent risks[1]. Risk management is the global process of identifying and controlling hazards or risks of adverse events within a defined population of stake-holders[2, 3]. In sport the most obvious group of stake-holders tend to be the participants; however secondary stake-holders may include the health care system, sporting clubs, sponsors and spectators. Risk management includes risk assessment and risk mitigation[3]. Risk assessment is the first stage in the risk management process. It involves the identification of risk factors and the way in which they impact on sports participants or other stake-holders. Subsequently, risk assessment involves risk estimation and risk evaluation[2]. The risk estimation process evaluates the magnitude of the effect while risk evaluation attempts to quantify the risk as acceptable or not.

The second function of risk management is risk mitigation[3]. Risk mitigation is the practice of identifying and implementing control measures to reduce the probability or consequences of risks[2]. In essence there are two control options to the risk mitigation process; risk acceptance or risk reduction[3]. Risk acceptance involves ensuring that the costs associated are covered. Risk reduction involves implementing preventative or therapeutic interventions in an attempt to minimise the impact of risk factors on stake-holders[2]. Preventative interventions may involve the uptake of procedures that minimise hazards, while therapeutic interventions may be applied by health care professionals such as doctors, physiotherapists and chiropractors to minimise the outcome of identified hazards.

Sports injury

Perhaps the most frequently encountered adverse event of exposure to sporting activity is sports injury[4]. In broad terms sports injury is the result of organised, competitive physical activity in which damage is inflicted on the body usually as the direct or indirect result of an external force, with or without disruption of structural continuity[5]. Many countries are adopting the goal of life-long physical activity, under the assumption that the health benefits outweigh the costs associated with such involvement[6-8]. While sport and physical activity provide physical, mental, social and economic benefits to the individual and the community, the adverse effects of sport and recreational activity are typically less commonly discussed and should be considered[4].

After home accidents, sporting injury ranks as the second highest cause of injury seen in emergency rooms, followed by traffic accident[9, 10]. Sporting injuries are infrequently serious with only 3% requiring a hospital stay[11, 12]. However, emergency room presentations may not reveal the true scope of the sports injury problem[11]. They may represent only the more severe sporting injuries, and studies which present data on emergency room presentations only may not account for sporting injuries which require attention from non-emergency health care practitioners[11]. This includes overuse injuries which tend to become chronic, or injuries which lead to degenerative joint disease. This consequence was recently identified in an Australian population health survey[11].

Sport injuries may burden the individual and community via lost time from sporting, social, education or work related activity[13]. The monetary costs are carried by the health care system, as well as employers and employees alike[14, 15]. The cost of sport/recreation related injuries in Australia has been estimated to be between $AUD1-1.8 billion per annum[1, 16, 17]. This does not account for the negative impact on future sporting participation or an individual's possible negative mental state.

Outcome measures of sport risk

There are two outcome measures in the estimation of sports injury risk[2]. These are sports injury incidence and severity[2, 13]. Incidence is perhaps the most basic measure of risk, which is the probability of developing a new condition in a given period of time. Importantly incidence data alone provides only half the epidemiological picture regarding the extent of any sports injury problem[13]. Sports injury severity is the outcome measure that reports the consequence[2]. These two measures can be used to estimate the risk of an activity or an injury causative factor[13]. Prevalence of injury, although not a measure of risk, is a measure or pervasiveness of a condition at a point in time.

Contact and collision sports

Rice *et al*[18] and the Council on Sports Medicine and Fitness[18] suggest that one way of determining the relative risk of an injury to the athlete is by categorising sports as 'contact', 'limited-contact', or 'no contact'. They subdivide contact sports into 'collision' and 'contact' sports; with collision implying a greater injury risk, although there may be no clear dividing line between the two[18]. Further, they suggest that in collision sports (e.g., boxing, ice hockey, football, lacrosse, and rodeo), athletes purposely hit or collide with each other or with inanimate objects (including the ground) with great force[18]. Collision sports can be further sub-divided into 'football' and 'non-football' sports (Table 1.1). Football broadly encompasses those team sports that are similar in origin and have incorporated to varying degrees kicking a ball with the foot in an attempt to score points.

Table 1.1
Examples of non-contact, limited contract, and contact/collision sports

Non-contact	Limited contact	Full contact or Collision	
		Non-Football	**Football**
Golf Curling Tennis Swimming Sprinting Cricket	Basketball Dancing Baseball Softball Field hockey Netball Soccer	Boxing Ice-hockey Lacrosse Rodeo Taekwondo Water polo	American football Australian Rules Football Rugby League Rugby Union Gaelic football

Football injuries in Australia

In Australia the concept of greater injury risk from collision sport is supported by the high comparative incidence and severity (hospitalisation) rates of the most frequently played collision football codes i.e. Rugby League[7, 19-21], Australian Rules Football[12, 19-23], and Rugby Union[19-21]. In 1993 Seward *et al*[20] estimated the sports injury incidence rates for these football codes in Australia to be: (a) 62 injuries /1000 player-hours for Australian Rules football; (b) 139 injuries /1000 player-hours for Rugby League and; (c) 53 injuries /1000 player-hours for Rugby Union. With respect to the severity of Australian sports injury, Flood and Harrison[19] suggest football is the most common sport associated with injury in terms of hospitalisations, with 12,600 admissions in 2002-03. They report 3,944 admissions were due to Australian Rules football, 3,270 due to soccer, 2,021 due to football other and unspecified, 1,612 due to Rugby League, 715 due to rugby unspecified, 522 due to touch football and 516 due to Rugby Union[19]. In terms of the severity of sports injury, expressed as a factor of mean hospital bed days, Rugby Union exhibited a severity of 3.2 mean bed days, followed by Australian Rules football and Rugby League sports injury with 1.8 and 1.7 mean bed days respectively. Rugby Union has a relatively high risk-contour that may approach society's acceptability threshold[2], in turn impacting on society most noticeable at the amateur level of the game[24].

Rugby Union (RU)

The object of RU is that two teams, each of fifteen players, via carrying, passing, kicking and grounding an oval shaped ball, score as many points as possible[25]. Contesting the ball possession is a key feature of RU. Most notably this can occur through extreme physical contact between opposition team members in an attempt to gain ball possession. This occurs through the tackle, ruck, maul and scrum. These and other terms in a RU event are discussed below.

Scrum

The purpose of the scrum is to restart play after a minor infringement or a stoppage in play. A scrum is an organised binding of 16 players (eight from either team) where the heads of the opposing front row players are interlocked. Individuals from either team bind together in three rows and push together in contestation for ball possession. A tunnel is created between the opposing front row players to which the ball, to be contested over via pushing, is thrown. A scrum is organised with players from both teams in the following manner: Three players bind together to form the 'front row' of the scrum to directly counter the force of the opposition. The middle player in the front row is termed the 'hooker'. The players on either side are termed the 'props'. From there two players then bind together to form the 'second row' or 'locks'. Once bound second row players then bind to the front row players by placing their necks and shoulders between the buttock and thighs of the hooker and prop on either side. The final three players termed collectively as the "back row" bind onto the sides of the second row player, with one of the back row players termed the "number eight" binding between the buttocks and thighs of the second row. Collectively these players bind together and push together in scrum contestation[25].

Line-out

The purpose of the line-out is to restart play after the ball has gone into touch (out of bounds), with a throw in between two lines of lineout players[25]. Lineout players are the players who form the two lines that make a lineout. Players taking part in the lineout are the player who throws in and an immediate opponent, the two players waiting to receive the ball from the line-out and the line-out players. In the modern game the player who throws in the ball must throw between the two opposing lines of line-out players. Contesting for ball position occurs by lineout players who jump to grasp the thrown-in ball. Jumping players may be supported by their team mates, who lift the jumping player to greater heights. The lineout ceases when the supported jumper is lowered to the ground.

Tackle

A tackle occurs when the ball carrier is held by one or more opponents and is brought to ground. The ball carrier brought to ground is termed the tacklee. Opposition players who hold the ball carrier and bring that player to ground, and who also go to ground, are known as tacklers[25].

Ruck/Maul (Loose Play)

Rucks and mauls are loose scrum like plays where players bind together and push together in contestation for ball position. They are termed loose play as they are not formally organised by the adjudicating referee. Law 16 states: A ruck is a phase of play where one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground. Open play has ended. Rucking: Players are rucking when they are in a ruck and using their feet to try to win or keep possession of the ball, without being guilty of foul play[25]. Law 17 states: A maul occurs when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's team mates bind on the ball carrier. A maul therefore consists of at least three players, all on their feet; the ball carrier and one player from each team. All the players involved must be caught in or bound to the maul and must be on their feet and moving towards a goal line. Open play has ended[25].

Open Play

Open play refers to additional player activity which occurs not at game restart situations, but in the field of play, excluding the tackle or ruck/maul phases of the game. In open play opposition players move themselves, frequently at speed, to: (a) avoid their opposition; (b) to approximate themselves with their opposition; (c) to kick the ball; (d) to mark the ball from a kick, and; (e) to ground the ball. Collision between players and the ground may occur in this phase of play.

The structural organisation of players on the RU field can reflect the functional role of individuals in the team. Loosely described, the rugby team can be divided into two functional groups, the forwards, and the backs (Figure 1.1).

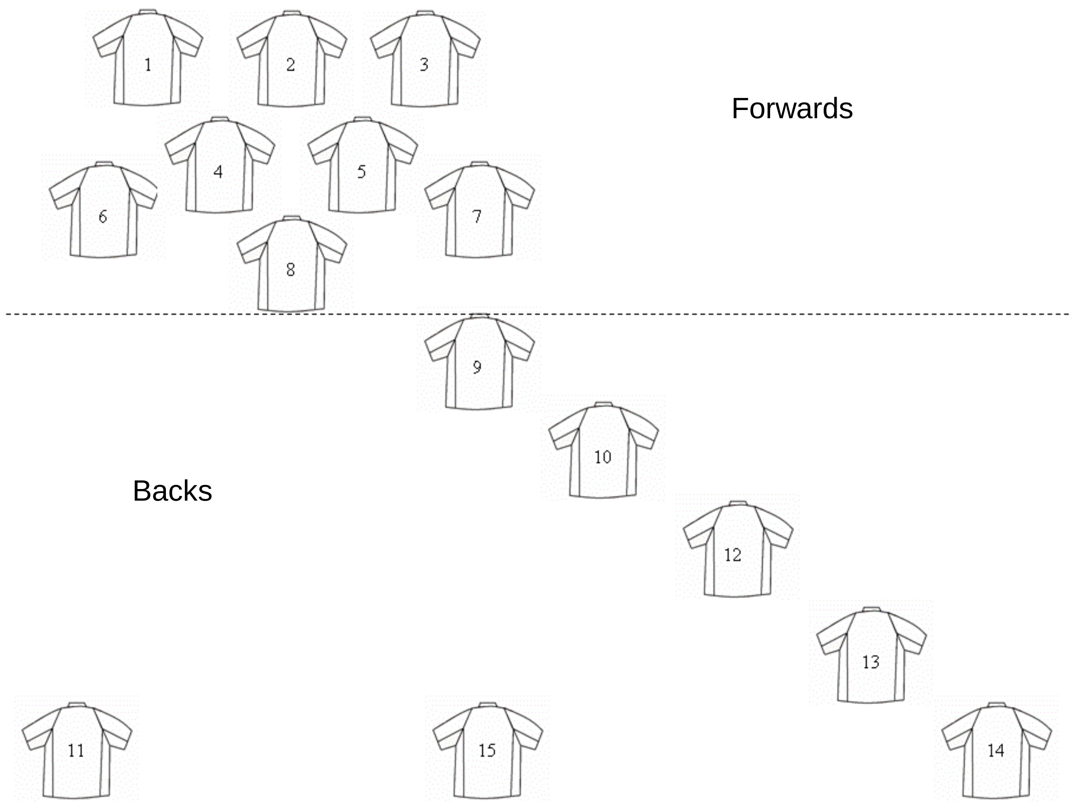

Figure 1.1 Rugby Union positions of play**:** 1. Loose-head prop; 2. Hooker; 3. Tight-head prop; 4. Second row; 5. Second row; 6. Blind-side flanker; 7. Open-side flanker; 8. Number 8; 9. Scrum-half (Half back); 10. Fly-half (Five-eighth); 11. Left wing; 12. Inside centre; 13. Outside centre; 14. Right wing; 15. Full back

The main function of the eight forward players (numbered 1-8) is to gain and retain ball position. They are the primary participants in the restarting (lineout and scrum) phases of play. The main function of the seven back players (numbered 9-15) is to gain field position and score points. They are the primary participants in the open play phase of the game. Quarrie *et al*[26] identified that forwards are generally taller, possessed greater body mass, and were more endomorphic and less ectomorphic than backs of the same grade. In addition the backs tended to perform better on physical performance measures than forwards, being more aerobically fit, faster, more agile, and possessing a higher degree of muscular endurance[26]. Different anthropometric characteristics have also been identified between forwards of different positional categories. In a later study Quarrie *et al*[27] identified that front row forwards (props and hookers) possessed highly endo-mesomorphic somatotypes, and typically rated very low for ectomorphy. The props possessed greater body mass than hookers. Second row and back row forwards were taller than the front row forwards. In terms of physical performance fewer differences were observed by Quarrie *et al*[27] Hookers performed better than props on an aerobic assessment. Locks and back row forwards were faster than the front row forwards on a 30m sprint from a running start, while the inside backs were shorter and lighter than the midfield and outside backs[27]. These anthropometric and physical performance characteristics are thought to reflect the functional requirements of the position of play[26, 27]. However, as the game of RU evolves, the functional, morphological and physiological characteristics of the various playing positions have become less distinguishable[24]. It has been noticed, since the advent of RU professionalism, that there has been an increase in ball-in-play time, tackles and mauls and a reduction in kicks, line-outs and scrums during game play[24]. Consequently, functional requirements of open and loose play, such as fitness and mobility, have become more pertinent to the RU player.

Neck Injury

RU, like the other Australian football codes, constitutes a good form of exercise[28]. However its physical nature combined with the absence of protective gear contributes to the high risk of injury associated with this sport[28]. While RU has a relatively high overall risk of injury, it has a small specific risk of fatal and catastrophic injury[29]. It is the fatal or catastrophic risk which generates a strong emotional response from society, due to the devastating effect on the individual and the community. This is particularly evident when such injuries occur in children or adolescents. The most devastating types of injury in RU are brain and spinal cord injury which can be associated with death, quadriplegia and paraplegia. The actual risk of catastrophic injury in Australian RU has been estimated at 4.4 catastrophic injuries /100 000 per year[29].

Even though the incidence of catastrophic injuries in RU is low[29] much of the literature on the subject reports the more serious cases and retrospective reviews[30], resulting in a skewed understanding of the neck injury problem. There are very few prospective neck specific studies reported in the RU literature[29].

Vital to any research on neck injury is a clear definition of the neck region. For the purposes of this dissertation, neck is the anatomic region outlined by Guzman *et al*[31] (Figure 1.2).

After 20 years of research on this topic, the true incidence of either spinal cord or all cervical injuries in RU is still unknown[32]. There appears to have been little research done on neck injury in amateur RU[24]. It has been suggested that for every debilitating spinal cord injury there may be as many as ten near misses[33, 34] constituting spine injury without permanent neurological dysfunction. There is a lack of association between hospital based spinal cord injury observations and field side cervical injury observations which fuels the speculation of this claim. It is not surprising that the larger proportion of neck injury observed field side in RU do not progress to spinal cord units for observation as they tend to be minor, constituting disruption of musculoskeletal structures[35, 36].

The early attempts to quantify the incidence of neck injury and validate prevention strategies in RU were held back by methodological short-comings. Moreover the early commentary on neck injury in RU was based on anecdotal evidence. Consequently these early studies lack scientific rigour.

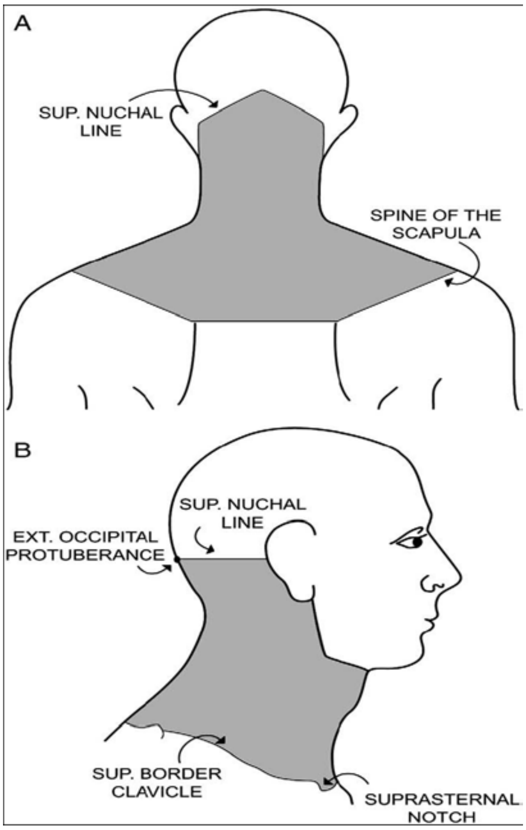

Figure 1.2 Guzman J, Hurwitz EL, Carroll LJ, Haldeman S, Cote P, Carragee EJ, et al. **A New Conceptual Model of Neck Pain. Linking Onset, Course, and Care: The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders**. *J Manipulative Physiol Ther*. 2009;**32**:S17-28. Figure 1, The anatomic region of the neck from the back (A) and the side (B); p. S19

The actual risk of non-catastrophic neck injury in amateur players is of particular interest to stakeholders in RU and the community. Most rugby is played at the amateur level[24]. Individuals who sustain a neck injury may suffer pain[37, 38] and disability[38, 39]; lose time from sport, school or work and social or recreation activities[13]. Monetary costs of neck injury are high and endured by stake-holders in the game and the health care system[15]. The long term health consequences of chronic pain and disability have only recently been considered[40-44], which further add to the health and monetary consequences of neck injury in RU.

Sports injury prevention

In 1992 van Mechelen *et al*[45] had published a public health article, which addressed the growing concerns of the Council of Europe on the unwanted side effects of sports injury that resulted from participation in sport. With the philosophy that "prevention is better than cure" the authors presented a benchmark model for the prevention of sports injury. They proposed a four step system which identified specific epidemiological factors in sport injury and provided prevention strategies designed to minimise the impact of sports injury. This model termed "the sequence of prevention" has the following steps: (1) Identify and describe the extent of the sports injury problem by gathering data on the incidence and severity of sports injury; (2) Identify the factors (aetiology) and mechanisms which play a part in sports injury; (3) Informed by step one and two, introduce measures that are likely to reduce the future incidence and/or severity risk/s of sports injury; (4) evaluate the effect of the preventative measures introduced by repeating the first and second steps (Figure 1.3).

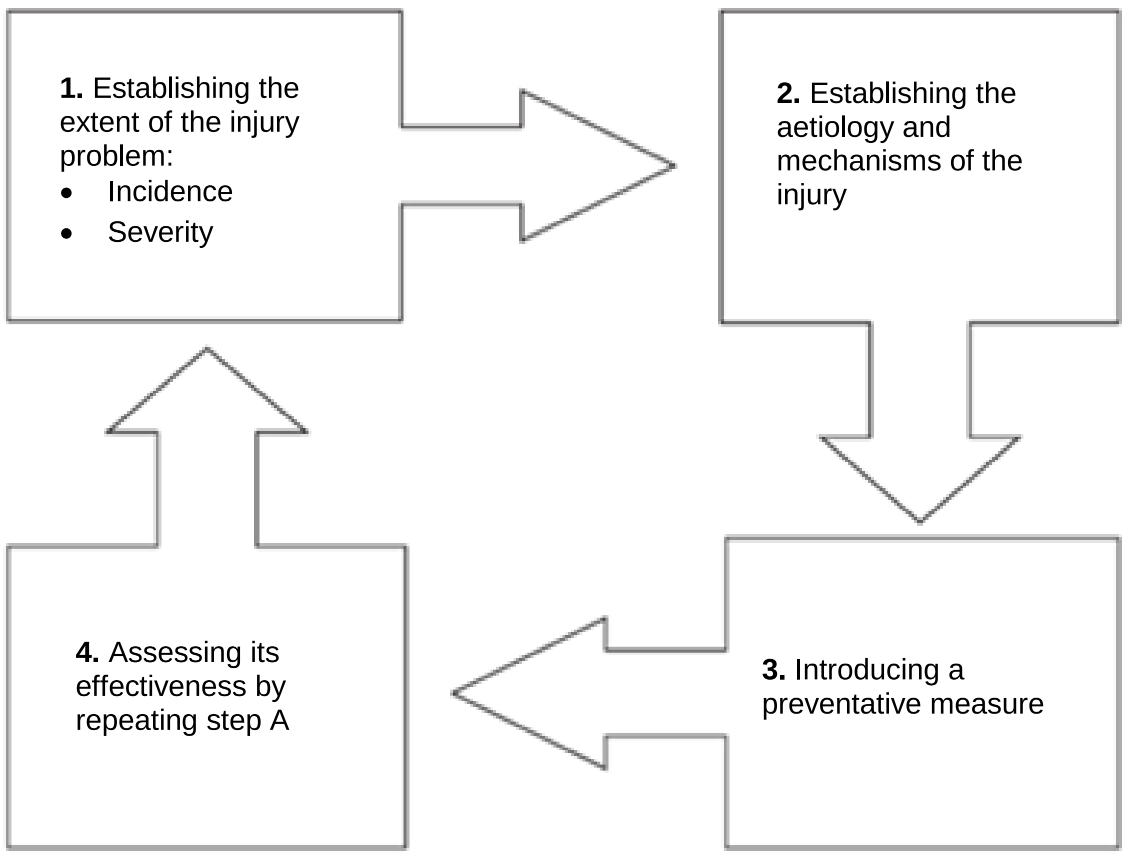

Figure 1.3 van Mechelen W, Hlobil H, Kemper HCG. **Incidence, severity, aetiology and prevention of sports injuries. A review of concepts**. *Sports Med*. 1992;**14**:82-99. Figure 1, The 'sequence of prevention' of sports injuries; p. 84

Since the model was proposed by van Mechelen *et al*[45] over a decade ago, the research and understanding of sports injury prevention has advanced considerably. Only recently have limitations associated with the four step sequence of prevention been highlighted, and modifications to this theoretical framework have been proposed[46, 47]. The limitations identified with the four step model of van Mechelen *et al*[45] occur after step three in the sequence of prevention. According to Finch[46] and van Tiggelen *et al*[47] the limitations include: (1) the efficacy of the preventative strategy proposed; (2) the efficiency of the proposed measures; (3) the compliance in adoption of preventative measures by participants in the sport;(4) the effect of risk taking behaviours of athletes, and finally; (5) the "real world" implementation of preventative measures.

Accordingly, modifications to the paradigm of van Mechelen *et al*[45] proposed by Finch[46] and van Tiggelen *et al*[47] include the addition of two intermediate steps, which follow step three: the proposal and implementation of preventative measures. The new steps recommend the implementation of proposed preventative measures and reflect on the validity and suitability of those measures for real world application. The new model involves further intervention based studies such as laboratory testing on a small number of participants, small group assessments, focus groups, or clinical trials to first evaluate the efficacy of the proposed measure usually under ideal conditions[46]. It ideally studies the efficiency, compliance and risk taking behaviour of the athletes[47]. Evaluation of efficiency considers the change in injury risk versus the potential benefit to all stakeholders in the sport. Further, it identifies whether the proposed prevention strategy is creating a risk shift as opposed to minimising risk. Risk shift can be described by the idiom "robbing Peter to pay Paul" which suggests one's debt is merely transferred from one person to another without truly being reduced. In a sports injury context this amounts to reducing the risk of injury in one aspect of the sport, while increasing injury risk in another. The success of proposed preventative measures lie with the compliance of the athlete. This is a learnt process, partly dependent on the athlete's experience of the injury risk and willingness to take up the measure. It can be biased by the athlete's attitude, behaviour and beliefs. Therefore the athlete's aptitude and threshold for risk taking behaviour also impacts on the compliance of athletes to adopt injury prevention strategies (Figure 1.4).

In parallel with the original model proposed by van Mechelen[45] the first two steps of the revised sequence described by van Tiggelen *et al*[47] are related to the epidemiological study of sports injury. Steps 4, 5 and 6 relate to the efficacy of intervention and are based on the studies which evaluate this.

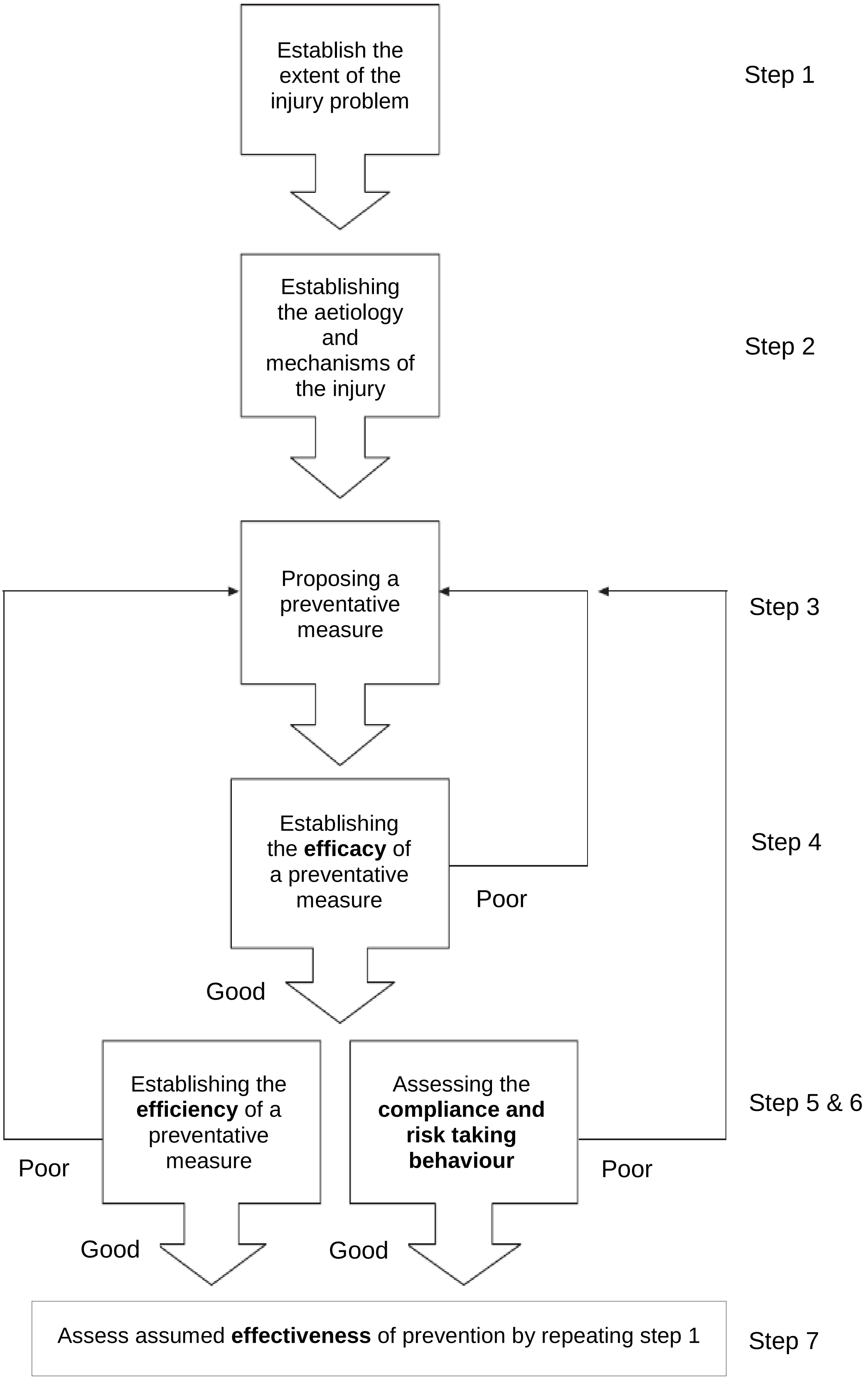

Figure 1.4 van Tiggelen D, Wickes S, Stevens V, Roosen P, Witvrouw E. **Effective prevention of sports injuries: A model integrating efficacy, efficiency, compliance and risk-taking behaviour**. *Br J Sports Med*. 2008;**42**:648-52. Figure 2, Sequence of prevention of overuse injuries; p. 650

Risk factors for sports injury

In the sequence of prevention[45], once a threat to an athlete's health has been identified, the second step is to establish cause. This amounts to determining why athletes are at risk and how the injury may happen[48]. From an injury prevention standpoint this is described as identifying risk factors, aetiology and mechanisms of injury.

Traditionally risk factors have been catagorised as 'intrinsic' and 'extrinsic' risks. Intrinsic risks pertain directly to the athlete[48]. Extrinsic risks pertain to environmental risk factors which are imposed externally onto the sports person in the athletic arena[48]. Additionally, risk factors may also be classified as 'modifiable' or 'non-modifiable'. Non-modifiable factors, such as the age of the athlete cannot be changed, whereas modifiable factors, such as the conditioning of an athlete, can potentially be changed through physical or behavioural training.

Understanding whether risk factors are internally or externally imposed is not sufficient to encompass a full understanding of an injury event. Further information regarding the mechanism and aetiology of the injury and its interaction with risk factors is required. Therefore it is likely that risk factor identification requires a multi-factorial model which takes into account the dynamic and complex interaction of several risk factors, and which ultimately leads to a sequence of events that result in sports injury[45, 48, 49].

Meeuwisse[49] proposes a dynamic model in which extrinsic and intrinsic predisposing factors can increase the risk of an injury event, but cannot cause an injury event to occur. In this model, extrinsic risk is described as an enabling factor(s) which when combined with an intrinsic risk factor(s) leave the athlete susceptible to injury without producing an injury event. However, the two combined create a susceptible athlete primed for possible injury. An inciting event is the final set of factors that results in injury in the susceptible athlete (Figure 1.5).

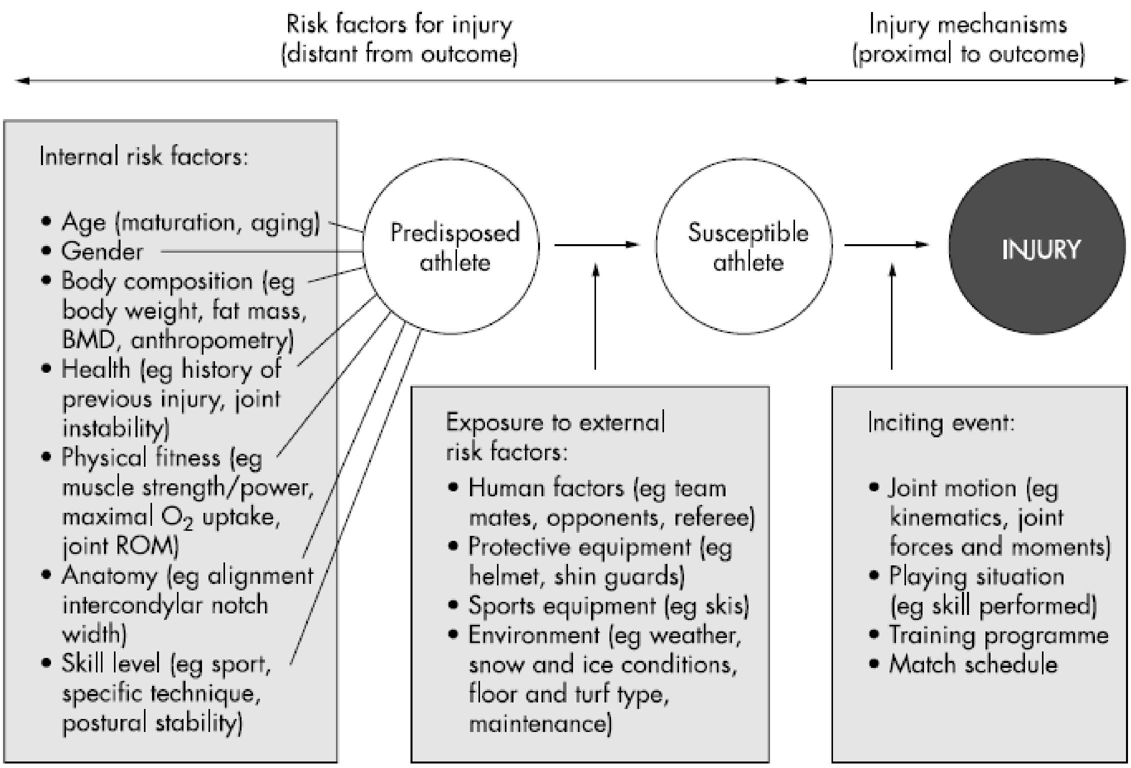

Figure 1.5 Bahr R, Holme I. **Risk factors for sports injuries - A methodological approach**. *Br J Sports Med*. 2003;**37**:384-92. Figure 1, A dynamic, multifactorial model of sports injury etiology - adapted from Meeuwisse (1994); p. 385

Aims and objectives of the thesis

This two year prospective cohort study on neck injury in RU focuses on the process of risk assessment to identify the probability, consequence and causes of non-serious neck injury. Guided by the sequence of sports injury prevention established by van Mechelen[45], Finch[46], van Tiggelen *et al*[47], and Bahr and Holme[48], this thesis aims to investigate neck injury in RU. The results from other prospective cohort studies in this regard are used to guide the project’s more specific aims which are to:

- Identify the incidence and severity of neck injury in RU
- Describe the location and type of neck injury in Australian men's amateur RU
- Propose preventative measures to minimise the impact of neck injury in Australian men's amateur RU.

Primary objective:

Measure the incidence and severity of neck injury in amateur Australian men's RU over the 2006 and 2007 playing seasons.

Secondary objectives:

Describe the aetiology and mechanisms of neck injuries in amateur Australian men's RU over the 2006 and 2007 playing seasons.

Identify risk factors for neck injury in amateur Australian men's RU over the 2006 and 2007 playing seasons.

The null hypothesis of the secondary objectives is:
In Australian amateur men's RU there is no association between either incidence or severity of neck injury and the mechanisms of neck injury or proposed risk factors.

Summary

The topic of this dissertation is the assessment of sports injury risk. Sports participation is associated with many health benefits. Conversely the unwelcome by-product of sports participation is sports injury. The sports injury problem poses a burden on the athlete, stakeholders in sport and the community alike. RU as a sport has a high overall risk of injury. In its most sinister form neck injury can be associated with catastrophic sequelae to the individual which affects the community as a whole. The true incidence and severity of the neck injury problem in amateur RU is still unknown. In the sequence of prevention of sports injury, objective risk assessment informs the risk mitigation process. The scientific process of preventing sports injury requires an accurate and reliable understanding of the sports injury problem. The aim of this thesis is to capture RU neck injury data via a two year prospective cohort study to inform the first and second steps in the sequence of prevention. In turn prevention measures have been proposed that can be later studied in the risk mitigation process.

CHAPTER TWO

LITERATURE REVIEW

This has been accepted for journal publication:

Incidence and severity of neck injuries in rugby union: a systematic review. **Swain MS**, Lystad RP, Pollard HP, Bonello R. *Journal of Science and Medicine in Sport*. 2010; *article in press.* Accepted 23-OCT-2010

Statement of authorship contribution of the MPhil candidate

In our role as co-authors of the journal publication ‘Incidence and severity of neck injuries in rugby union: a systematic review. **Swain MS**, Lystad RP, Pollard HP, Bonello R. *Journal of Science and Medicine in Sport*. 2010; *article in press.*’

We confirm that Michael Steven Swain has made the following contributions:

- Concept and design of the research: MSS 80%, RPL 10%, HPP 5%, RB 5%
- Retrieval and preparation of the manuscript content: MSS 90%, RPL 10%
- Inclusion criteria: MSS 60%, RPL 40%
- Quality assessment: MSS 60%, RPL 40%
- Critical review: MSS 70%, RPL 10%, HPP 10%, RB 10%
- Writing: MSS 85%, RPL 5%, HPP 5%, RB 5%

Michael S. Swain__________________________________ Date: ______________

Reidar P. Lystad__________________________________ Date: ______________

Henry P. Pollard__________________________________ Date: ______________

Rod Bonello_____________________________________ Date: ______________

Due to copyright laws, the following articles have been omitted from this thesis. Please refer to the following citations for details.

Swain M. S., Lystad R. P., Pollard HP, Bonello R. (2010) Incidence and Severity of Neck Injuries in Rugby Union: A Systematic Review. *Journal of Science and Medicine in Sport*. 2010, Vol. 14, Issue 5, p. 383-389
DOI: http://dx.doi.org/10.1016/j.jsams.2010.10.460

CHAPTER THREE

METHODOLOGY

In part Chapter Three was presented on podium as:

Cervical injuries in rugby union: Incidence severity, aetiology and prevention: A prospective cohort study, a presentation of methodology. **Swain MS**, Bonello R, Pollard H. 2006 Conference on Chiropractic Research. Chicago, Illinois, United States of America - 15-16 September, 2006.

Statement of authorship contribution of the MPhil candidate

In our role as co-authors of the podium presentation "Cervical injuries in rugby union: Incidence severity, aetiology and prevention: A prospective cohort study, a presentation of methodology. Swain MS, Bonello R, Pollard H. 2006 Conference on Chiropractic Research. Chicago, Illinois, United States of America - 15-16 September, 2006."

We confirm that Michael Swain has made the following contributions:

Concept and design of the research: MSS 80%, HPP 10%, RB 10%

Critical review: MSS 60%, HPP 20%, RB 20%

Writing: MSS 80%, HPP 10%, RB 10%

Michael S. Swain__________________________________ Date: _____________

Henry P. Pollard _______________________________ Date: _____________

Rod Bonello _______________________________ Date: _____________

Methods

This Chapter provides the methodological details of a two-year prospective cohort study that identified the incidence, severity, aetiology, and risk factors associated with neck injuries in an Australian amateur men's Rugby Union (RU) population over the 2006 and 2007 RU seasons in Sydney, Australia. It is expected that information derived from this study will inform the risk assessment component of sports injury management. As such preventative measures can be proposed for further study in the process of risk mitigation.

Recruitment

Approval was obtained from the Ethics Review Committee (Human Ethics) Macquarie University (reference number: HE24FEB2006-M04460) to recruit up to 400 participants (Appendix B). Written approval was granted by senior club representatives and sports medicine personnel to conduct the study. Inclusion criteria were set at participants being male, aged 18 years or older, who were registered to participate in competitive Rugby Union (RU) during the study period. Participation of RU players was voluntary with participants free to withdraw from the study protocol at any time. Information was provided to all eligible participants and their consent was sought for participation. Players gave written consent to participate in the study. Participants did not receive reward, monetarily or otherwise, for their participation in this study.

Time line

A prospective cohort study design was adopted for two continuous (2006 and 2007) Australian men's amateur RU playing seasons. The study design included a baseline survey and physical assessment. The baseline survey and physical assessment was conducted during the player recruitment period prior to the commencement of the season. The player recruitment period coincided with the Australian men's amateur RU playing preseason. Participant recruitment began February 2006 and February 2007 respectively, and was conducted at four scheduled preseason training sessions per club during this time. The 2006 rugby season participant observation period began 24 March 2006 and ended 16 September 2006. The 2007 rugby season participant observation period commenced 7 April and ended 22 September 2007. The study periods coincided with one week prior to and one week after the end of the respective Australian amateur men's RU playing seasons. The competition finals (quarter-finals, semi-finals and grand final) where played over three week commencing mid-August of the respective years. Longitudinally, neck injury events were recorded and tracked by two trained health professionals immediately following an injury.

Cohort study designs are most preferred in observational studies when all data is collected prospectively in a standardised manner. This is because prospective cohort studies can provide direct and accurate estimates of incidence and relative risk[48]. This approach involves measuring potential risk factors before injuries occur, after which new cases and exposure are reported during a period of follow up[48].

Study population

Participants were Australian men who play RU at the amateur level. A senior representative (president or head coach) of the RU clubs was initially contacted by telephone and an expression of interest to participate was sought. Following expressed interest, a letter of information and consent was sent to the corresponding individuals which was signed and returned prior to participant recruitment. Due to accessibility the two RU clubs chosen were (1) Northern Suburbs Rugby Union Club, and; (2) Lindfield Rugby Union Club. They were chosen as the chief investigator is affiliated with both RU clubs as either: (a) a previous player (Northern Suburbs Rugby Union Club) or, (b) the current sports medicine officer (Lindfield Rugby Union Club). Participant recruitment was voluntary. A general announcement was made at four separate training seasons per club which outlined the study objectives and the participant's involvement. On expression of interest, participants were asked to read and sign an information and consent form (Appendix C) then complete a self reported questionnaire as well as undertake a physical assessment procedure.

The competition (level) of play for these clubs differs. Northern Suburbs Rugby Union Club competes in the Sydney premier RU competition, while Lindfield Rugby Union competes in the Sydney metropolitan suburban RU competition. Sydney premier RU is considered to be the highest level of amateur RU competition in the Sydney metropolitan area. Rugby clubs generally train twice a week and compete against opposition clubs once a week on a Saturday. Sydney premier RU is generally the pool from which elite RU organisations recruit. Northern Suburbs Rugby Union Club schedules two training seasons a week and a scheduled competition once a week during the RU season. Sydney suburban RU clubs vary in training frequency from once a week to twice a week. They compete against opposition sides on Saturdays. The Sydney suburban RU competition is larger in terms of player numbers than the premier competition as it has six sub-competitions or sub-divisions which reflect further tiering in the level of play. Lindfield Rugby Union Club competes in the second division suburban RU competition. The club schedules two training sessions a week and one competition fixture once a week during the RU season.

Both Northern Suburbs Rugby Union Club and Lindfield Rugby Union Club have enough players to field more than one RU team. Indeed they can organise at least four teams which are graded in ability. First grade are considered the club's highest level players while fourth grade may be considered the club's lowest level players. All participants recruited play in senior grades at either club (aged 18 years of age or older). Both clubs field four senior grades on a weekly basis. Participants in both clubs are considered amateur players, as any remuneration offered (cash payment, rent or living expenses, rugby equipment) by either club is minimal and does not constitute a primary income source.

In Australia national RU participation figures for 2006 and 2007 indicate there were 193,382 and 189,914 total RU participants respectively[50]. This consists of senior, junior, schools, women and golden oldies subgroups. There was 37,278 senior men participating and in 2007 there was 36,370 senior men participation in RU in Australia[50]. The New South Wales (NSW) RU figures indicate in 2006 there were 18,949 and in 2007 there were 18,398 senior men participating in NSW RU[50]. The overall trend in Australian RU indicates participation has declined from 2006 to 2008.

Cohort

Objective social, demographic and economic details of this RU player cohort are limited to the study data. The age range of participants was 18 to 59 years (mean age: 24.1 years ± 5.7 years). Participant's playing experience ranged from 0 to 48 years (mean 12.5 years ± 6.3 years). Alcohol consumption ranged from 0 to 50 drinks per week (mean 12.3 drinks ± 7.9 drinks). White collar occupations accounted for 77.1% of the participants, while 19.4% were blue collar workers. The ethnic origin of the cohort was 84% Anglo-Australia background and 16% other.

Setting

The study was set in Sydney, New South Wales, Australia. The cohort participated in RU primarily in the northern suburbs of Sydney. During the competitive RU season these clubs generally alternate home and away fixtures which extend only within the Sydney Metropolitan region. Training seasons and home fixtures were undertaken, weather permitting, at North Sydney Oval, North Sydney, NSW and Soldiers Memorial Park, Lindfield, NSW.

Study size

Achieving desired levels of participants in cohort studies limit the occurrence of Type I and Type II errors[51]. There is typically no mention of how sample size has been calculated in prospective studies which evaluate neck injury in RU; therefore it is difficult to interpret the results of these studies. The main disadvantage of the cohort study design is the need to include and monitor large numbers of athletes for a long study period[48]. The counter argument posed by Rothman *et al*[52] is that study size formulae are purely mathematical and do not account for anything not included in the variables, therefore they should serve only to provide a rough guideline.

The sample size feasibility calculation reflects the regression models utilised in the assessment of risk factors, which supports the Bahr and Holme[48] concept that sample size depends mainly on the expected effect of the risk factor on injury risk. Further, Bahr and Holme[48] estimate that in prospective cohort studies 20–50 injury cases are needed to detect moderate to strong associations, whereas 200 injured participants are needed for small to moderate associations[48].

Study size calculation was performed using two sample-size formulae. The first was the common observational study method described by Kelsey *et al*[53] and Fleiss *et al*[54] and according to this, the standard parameters of: (a) 95.0% confidence level, (b) power at 80.0% chance of detecting a significant finding, (c) ratio of exposed to unexposed as 1.0, and, (d) percent of unexposed with outcome at 5.0%, was calculated with the estimate that 15.0% of participants exposed would sustain neck injury. The sample size required for this method was calculated at 282 participants. Practical restraints and resources inevitably limit study size[52]. The actual study size of this cohort was 262 participants.

Variables

Quantitative variables

Guided by the primary objective, two outcome measures were used as quantitative variables: (1) neck injury incidence or injury rate, and; (2) neck injury severity.

Neck injury rate was reported as the number of neck injuries per 1000 player hours. Attempts were made to measure actual risk exposure time by including training time in exposure time. Exposure time was estimated based on the numbers of players' in squads and typical training and match durations. The formula using the methods described by van Mechelen[45], Hodgson[55], Quarrie *et al*[56], and King *et al*[57] is:

$$\text{Incidence} = 1000 \times \frac{(\text{number of neck injuries per season})}{(1.33\text{ games} + \text{training hours})(\text{number of participants})}$$

Hodgson[55] concludes that incidence rates that do not consider exposure cannot reliably indicate the sports injury problem and should not be used to compare injury incidence. In this method incidence was calculated as a factor of exposure time. The inclusion of training time in the calculation of exposure time provides the flexibility to report match injury incidence as well as training injury incidence as a factor of these respective components of RU. King *et al*[57] have recently defined both match and training exposure for studies in Rugby League. While that paper was published after the commencement of this study, the method described by King *et al*[57] is consistent with the methodology used in this thesis. In summary, King *et al*[57] outline exposure time as the product of the number of players, and the number of matches or training sessions, multiplied by the duration of either match or training sessions, in a given period of time. Further, they advocate not adjusting for the technical aspects of the match such as golden point, or temporary play suspensions that may prolong a game. However, several authors[58, 59] have suggested that the approach of King *et al* may lack the precision of individual player logs to determine exposure time. Due to the time and cost constraints, this is only typically afforded to the logistical capabilities available in surveying professional athletes.

Neck injury severity was reported as the number of weeks lost from play, grouped as 'minor' (less than one week lost from play), 'mild' (1-2 weeks lost from play), 'moderate' (2-3 weeks lost from play) and 'severe' (3+ weeks lost from play).

Additionally, information regarding the duration and nature of treatment, time lost from work or school and permanent damage as a result of injury was recorded. There is inconsistent use of severity as an outcome measure for sports injury risk in athletic populations in the liturature[30]. However, severity as a factor of the length of time lost from participation is frequently adopted in injury surveillance, but variability exists in the way time lost is recorded[13]. Sports injury studies tend to arbitrarily group the severity of injury according to duration as: slight, minor, moderate and severe, but use different time criteria to make this judgement. Prior to the commencement of this thesis the trend was to group severity to reflect the weeks lost specifically from play[21, 60].

Non-quantitative variables

The secondary objectives of this dissertation were to assess the specifics of neck injury. Variables identified were neck injury aetiology, mechanisms, type and risk factors in Australian amateur men's RU. To date RU injury surveillance studies have included the phase of play in their description of sports injury aetiology[61-65]. This study continues this trend. Phases of play were scrum, tackle, lineout, ruck, maul, kicking, pileup, collision, or other. Mechanism of injury describes forces applied to the cervical spine during a neck injury event: flexion, extension, rotation or side bend, or the non-physiological motion of cervical spine compression. Cervical spine compression occurs when an axial load is applied to the vertex of the head[66-68]. The injury type was classified as either the nature of the injury[69-71] or the specific bodily structure of injury[72]. The nature of injury includes for example: muscle strain, ligament sprain or a bone fracture. The specific bodily structure of sports injury is the specific tissue affected. In effect this process of identifying neck injury type involves diagnosing the tissue that has the lesion.

Risk factors included in this study are found in RU literature or are hypothesised as risk factors by the chief investigator based on his personal experience of managing RU sports injury. Risk factors proposed in the literature are: player's age[69], alcohol consumption[56], occupation[73], ethnic origin[74], RU experience and stage of player's career[75-77], position of play[78, 79], grade of play[69, 72, 80], volume of preseason preparation[81], type of preseason preparation[56, 81], game versus training[82-84], phase of play[76, 85-88], time of game or season[82, 89, 90], legal versus illegal play[78, 91, 92] and inadequate neck strength[93-96]. Risk factors hypothesised by the chief investigator include: current neck injury, previous neck injury, neck mobility/available motion, pain generated from neck motion, and poor neck function (deep neck flexor stability). As mentioned, practically all attempts to measure risk factors for neck injury in RU lack analytical rigour. Based on the paucity of scientific scrutiny directed at risk factors for neck injury in RU the stated risk factors are, perforce, subject to the same weakness.

Neck injury definition

An all encompassing sports injury definition was adopted. Neck injury was defined as any injury to the neck region which was sustained as a result of participation in RU which caused a reduction in the amount or level of sports activity, or a need for advice or treatment, or adverse social or economic effects[24, 97]. The definition for neck region has previously been given in Chapter one.

Prior to the commencement of this dissertation, consensus in the literature on the most appropriate definition and methodologies to standardise the recording of sporting injuries and reporting of studies in RU had not been achieved. Therefore guided by the commentary of van Mechelen *et al*[45] and Lower[97] the widely accepted and agreed upon definition by the Council of Europe was adopted here. The Council of Europe is a supranational organisation composed of virtually all of the countries of Europe and is primarily a consultative body. Consequently all neck injuries incurred during the observation period were recorded, including transient injuries which were those injuries that did or did not require medical attention and resulted in no time lost from match play or training.

Data collection

The baseline measure (Appendix D) completed prior to the commencement of the RU season consisted of a self directed questionnaire and a physical examination of the neck region. The self reported questionnaire included identifying details such as the player’s name and age, as well as 13 factual type questions which canvassed the earlier proposed neck injury risk factors of participants. The questionnaire was not scrutinised for scientific validity prior to its implementation, however efforts were made to limit question ambiguity and the need for sophisticated cognitive judgement.

The physical examination consisted of: (1) a cervical spine range of motion (ROM) assessment which evaluated overall neck mobility with or without the presence of pain. Visual estimation method was employed as described by Magee[98] and as evaluated by Youdas *et al*[99]; (2) a cervical stability test, which can be described as a modified version of deep neck flexor strength/control test as described by Jull *et al*[100].

This method has further been described by Murphy[101]; (3) a cervical spine isometric pre-participation strength assessment in which the athlete holds their bodyweight using their cervical spine at a 45 degree angle. This method has previously been described by Zachazewski *et al*[102]. The physical examination routine was standardised for all participants and implemented by two tertiary educated and New South Wales registered chiropractors trained in the implementation of the research protocol. The physical examination routine adopted was modelled on the cervical spine physical examination routine currently taught to master level chiropractic students at Macquarie University, Sydney, Australia. Retraining in methods used in this study protocol was conducted for the two chiropractors who performed the baseline assessment.

Neck injury event data (of incidence, severity, aetiology, mechanism and type) was recorded using a modified version of the Rugby Union Injury Report Form for Games and Training (RUIRF) (Appendix E) as descried and evaluated by McMannus[60]. The RUIRF was modified to collect additional details specific to neck injury such as symptoms of neck injury, visual range of motion findings, other physical orthopaedic findings plus techniques, modalities and advice used in the management of neck injury. Two data collectors recorded the neck injury details on the modified RUIRF. The first data collector was the chief investigator who is a New South Wales registered chiropractor and the sports medicine officer at Lindfield Rugby Club. The second data collector was an Australian Physiotherapy Association registered sports physiotherapist who was employed as Northern Suburbs Rugby Union Club head physiotherapist. Data collectors fitted the data collector’s inclusion criterion which was a relevant tertiary level qualification to manage sports injury. Data collectors attended all scheduled trainings and competitive matches during both the pre-season and competitive RU season. Both data collectors were trained prior to commencement of the observation period in the use and role of the modified RUIRF. The modified RUIRF training consisted of two scheduled meetings. The RUIRF was adapted in this study protocol as it is, to the best of the chief investigator's knowledge, the only validated instrument for data collection in RU. Further discussion on this tool's validity appears later in this Chapter.

The Orchard Sports Injury Classification System – version 8[103] (OSICS-8) (Appendix F) was incorporated into the RUIRF, facilitating the capture of data relevant to neck injury type. Several tools were available to assist in the capture of neck injury type data[104], however the Orchard Sports Injury Classification System (OSICS) and the International Classification of Disease (ICD) appeared to be most widely used and were considered for adoption due to their comparability. In 2005 Rae *et al*[104] compared the ease of application and the inter-coder reliability of both the OSICS-8 and the ICD-10-M in sports medicine diagnosis. Both systems demonstrated shortcomings and fell below the excepted level of 70% agreed validity set by Bensing at the 10th WONCA Conference on Family Medicine[104, 105]. Because the OSICS-8's development was specifically for sports medicine injury research the 57.2% agreement for OSICS-8 was better received than the 35.3% agreement identified for the ICD-10-AM. The OSICS-8 was adopted in this method as it was: (1) freely available, unlike the national athletic injury/illness reporting system; (2) the preferred system when compared to the international classification of diseases-10-Australian modification (ICD-10-AM)[104], and; (3) used previously in Australian football codes[106] and is likely to be used again in the future, which may account for comparability of this methodology.

Data handling

Following each participant recruitment session the baseline assessment forms as well as the information and consent forms were compiled and collected by the chief investigator. Personal information, responses to the 13 questions and physical exam findings were tabulated with the aid of a Microsoft excel spreadsheet. Data was checked and manually entered into the spreadsheet by the chief investigator. This process of baseline data entry was conducted twice in 2006 and 2007, over a period of two weeks following the completion of the respective year's participant recruitment.

In-season neck injury data was tracked via a weekly telephone call by the chief investigator to the secondary data collector during the observation period. Completed modified RUIRF were compiled and collected from the data collector by the chief investigator twice throughout the respective 2006 and 2007 RU seasons. On collection of the modified RUIRF data, it was entered manually into a second Microsoft excel spread sheet.

Single data entry was conducted by the chief investigator for the baseline data as well as neck injury data during the 2006 and 2007 RU seasons. A final data check was conducted for all data following the completion of the 2007 RU season.

Data analysis

Data analysis and statistical methods were employed on the advice of an expert statistician. Data analysis commenced July 2008. Data analyses were structured in terms of the specific research objectives, guided by the research questions. Initial data analysis of the baseline and neck injury data involved identification of neck injury incidence and severity, as well as neck injury aetiology and mechanisms of neck injury. Several follow-up analyses were conducted on the spread sheet data. Follow-up analysis was specific to analysis of neck injury and risk factor association. Statistical analyses were conducted over 12-18 months through ongoing correspondence between the chief investigator and the statistician.

Statistical methods

Associations between outcome measures (incidence and severity) and risk factors have been shown by means of a cross tabulation. Consistent with the commentary of Bahr and Holme[48] more formal analysis of risk and incidence injury required fitting Poisson regression models to assess the risk factors, with an offset (i.e. scaling factor) to take into account the number of player-hours in each of the risk sets. These analyses were undertaken using the statistical package GenStat. Also consistent with Bahr and Holme[48] associations with injury severity were primarily conducted using ordinal logistic regression models. These analyses were undertaken using the statistical package Minitab. Using a two tailed test protocol and an alpha level of 0.8, a probability level of $P < 0.05$ was considered statistically significant, although values in the range $0.05 < P < 0.10$ are worth commenting on for potential associations[107]. Where appropriate 95% confidence intervals (CI) were calculated. Consistent with Ulm[108], these have been based on Poisson and binomial distribution assumptions for incidence and percentage results respectively. They were obtained using the standard errors of parameter estimates from the GenStat generalised linear model procedure.

Bahr and Holmes[48] suggest a multivariate statistical approach should be used in studies which evaluate sports injury risk factors. In this cohort study a Poisson regression model was used for multivariate analysis of injury incidence events. This model was used as the outcome variable of incidence was assumed to come from a Poisson distribution. With respect to severity data, the dependent variable categories were ranked. Therefore the ordinal logistic regression model was adopted.

Validity

Attempts were made to recruit all senior players by organising several recruitment sessions pre-season, thus minimising the effect of a non-response bias. Consideration was given to participants who volunteer in good faith. Not all players participated, partly because not all were involved in pre-season training when recruitment occurred. Clubs were able to participate with minimal disturbances to normal operations. To minimise the imposition on the players, the RU clubs limited baseline data capture time to a five minute process per participant. Selection bias is thought to have been limited due to the uniformity of the target population.

The overall prospective design of this study eliminates recall bias. However as is the nature of self reported questionnaires, recall bias did exist in the retrospective elements of the baseline questionnaire. To minimise recall bias in the questionnaire the number of questions which relied on recall were limited. Further, the recall was short term to minimise recall bias. The questionnaire was structured based on current time events and to not be cognitively challenging.

Reporting bias was reduced using the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) cohort study checklist[36]. STROBE (Appendix G) is a 22 point checklist which recommends the reporting of key methodological issues for greater transparency and standardisation of observational studies in epidemiology[109].

The use of independent tertiary qualified and trained data collectors for RU clubs strengthened this study, and reduced affiliation and reporting bias. The tertiary qualified health care professionals in this study specialise in sports injury management. Training of data collectors in the use of the modified RUIRF strengthened its reliability. A similar prospective study in RU found that injury details collected by non-sports medicine experts are limited in scope[36]. Having the primary data collectors attached to each club throughout the season improved the familiarity and the timely collection of data. The adoption of a standardised data collection procedures and the fact that the data was collected by trained collectors enhanced the external validity of this process.

An all encompassing definition for sports injury was adopted in this study protocol because it limits exclusion bias introduced when a restrictive definition is implemented[110] and increases external validity[111].

In 2000 McMannus[60] reported on the validity of the RUIRF for data collection. At the time, there was no gold standard to assess the validity of data collection tools in sports injury surveillance. Therefore a 22 member panel plus four sporting bodies volunteered to assess the validity via video analysis and the Delphi technique[112]. Furthermore intra-rater and inter-rater reliability were assessed. Face, content and criterion validity was successfully assessed with 98.5% agreement. Intra-rater and inter-rater reliability each had 98% agreement. It was recommended that widespread adoption of the form should be implemented in the collection of injury data at all levels of RU for the acquisition of consistent data across the sport.

Several authors of sports epidemiology have identified limitations in the interview when assessing mechanism of neck injury[24, 71, 113, 114] in that the injury happens at such a high speed and the potential for brain injury may limit player recall. Video and laboratory analysis of motion may be a better assessment tool[24, 113, 114]. High technology methods of evaluating the mechanism of neck injury in this study were not logistically possible, therefore the commonly used technique of player interview was applied and the limitations acknowledged. Attempts were made to limit recall bias by interviewing the player immediately after the injury event.

There is some uncertainty in the literature regarding the assessment of tissue-in-lesion through physical assessment methods. The debate lies with the accuracy and reliability of tissue in lesion diagnosis through physical assessment methods[115-118]. It is argued that until physical assessment procedures are developed that are accurate and reliable, more valid methods such as magnetic resonance imaging (MRI) and ultrasound are the only truly meaningful ways to assess this injury. Cost and infrastructure limitations prohibited the use of such equipment in this study protocol. In addition the chief investigator questions the real world practicality of such an approach. The clinical assessment method coupled with the OSICS-8 was adopted for its practicality. The OSICS and now the later Orchard Sports Injury Classification System version 10 (OSICS-10) have been widely accepted in observational studies in RU. The primary advancement of the OSICS-10 over the OSICS-8 is the greater depth of diagnostic classifications which is thought to improve inter-user agreement.[119] The OSICS-10 was not adopted in this study protocol as it was not available at the time of study commencement. The use of the OSICS-8 coupled with the clinical assessment method of injury type classification and an all encompassing definition of reporting injury rate strengthens the inter-study comparability of this study.

Conflict of interest

None of the researchers involved in this study have a direct or indirect conflict of interest in the conduct of this research, monetarily or otherwise.

Project Management

Participating institutes and persons

- Chief investigator: Mr. Michael S. Swain[1]
- Primary supervisor: Assoc Prof. Henry P. Pollard[1]
- Associate supervisor: Assoc Prof. Rod Bonello[1]
- Secondary data collector: Ms. Amanda Turner[2]

- Statistician and statistical advisor: Assoc Prof. Peter Thompson[3]
- Lindfield Rugby Union Club
- Northern Suburbs Rugby Union Club

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CHAPTER FOUR

RESULTS

Chapter Four is presented in journal article format:

(1) **Swain MS**, Pollard HP, Bonello R. Incidence, severity, aetiology and type of neck injury in men's amateur rugby union: A prospective cohort study. *Chiropractic and Osteopathy*. 2010;18. Accepted 01-JUL-2010

(2) Risk factors for neck injury in men's amateur Rugby Union: a prospective cohort study. **Swain MS**, Pollard HP, Bonello R, Whillier S. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology*. 2010; *in review*

Ethics approval was granted from the ethics review committee (human research), Macquarie University, Sydney, Australia (reference number: HE24FEB2006-M04460).

Statement of authorship contribution of the MPhil candidate

In our role as co-authors of the journal publication ‘Swain MS, Pollard HP, Bonello R. Incidence, severity, aetiology and type of neck injury in men's amateur rugby union: A prospective cohort study. *Chiropractic and Osteopathy*. 2010;18.’

We confirm that Michael Steven Swain has made the following contributions:

- Concept and design of the research: MSS 70%, HPP 15%, RB 15%
- Data retrieval and preparation of the manuscript content: MSS 90%, HPP 5%, RB 5%
- Critical review: MSS 60%, HPP 20%, RB 20%
- Writing: MSS 90%, HPP 5%, RB 5%

Michael S. Swain________________________________ Date: ______________

Henry P. Pollard________________________________ Date: ______________

Rod Bonello____________________________________ Date: ______________

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CHIROPRACTIC & OSTEOPATHY

RESEARCH Open Access

Incidence, severity, aetiology and type of neck injury in men's amateur rugby union: a prospective cohort study

Michael S Swain*, Henry P Pollard and Rod Bonello

Abstract

Background: There is a paucity of epidemiological data on neck injury in amateur rugby union populations. The objective of this study was to determine the incidence, severity, aetiology and type of neck injury in Australian men's amateur rugby union.

Methods: Data was collected from a cohort of 262 participants from two Australian amateur men's rugby union clubs via a prospective cohort study design. A modified version of the Rugby Union Injury Report Form for Games and Training was used by the clubs physiotherapist or chiropractor in data collection.

Results: The participants sustained 90 (eight recurrent) neck injuries. Exposure time was calculated at 31143.8 hours of play (12863.8 hours of match time and 18280 hours of training). Incidence of neck injury was 2.9 injuries/1000 player-hours (95%CI: 2.3, 3.6). As a consequence 69.3% neck injuries were minor, 17% mild, 6.8% moderate and 6.8% severe. Neck compression was the most frequent aetiology and was weakly associated with severity. Cervical facet injury was the most frequent neck injury type.

Conclusions: This is the first prospective cohort study in an amateur men's rugby union population since the inception of professionalism that presents injury rate, severity, aetiology and injury type data for neck injury. Current epidemiological data should be sought when evaluating the risks associated with rugby union football.

Background

Neck injury in Rugby Union (RU) has a potential for devastating consequences[1]. For every debilitating spinal cord injury there may be as many as ten near misses[2,3]. Long term health implications, such as acquired degenerative change, have been reported from repetitive traumatic forces to the neck in RU [4,5].

The scientific process of preventing sports injury requires accurate and reliable understanding of the sports injury problem[6]. This initially surmounts to identifying the probability and consequence of the sports injury problem[7]. Subsequently aetiology and risk factors of the sports injury problem are then identified. With this knowledge the sequence of events which leads to sports injury can be objectively described and risk mitigation processes can be informed[8].

It is estimated neck injury accounts for between 3.5%[9] and 9.0%[10] of total injuries sustained in men's amateur RU. Only a small number of prospective cohort studies provide comparable inter-study definition on neck injury incidence and type in RU, albeit they are in either junior or professional populations[11-16]. There is a paucity of neck injury incidence, severity, aetiology and type data from amateur men's RU populations. This is particularly notable since the 1995 inception of professionalism in RU[17]. Amateur men are thought to comprise a large proportion of the 3 million strong rugby playing community[18].

The objective of this report was to present data on the incidence rate, severity, aetiology and type of neck injury in a cohort of Australian men's amateur RU playing population.

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Methods

Ethics approval was granted from the ethics review committee (human research), Macquarie University, Sydney, Australia (reference number: HE24FEB2006-M04460). Written approval was granted by senior club representatives and sports medicine personnel to conduct the study. Players gave written consent to participate in the study.

A prospective cohort study design was applied through the 2006 and 2007 rugby union seasons. Participants were recruited from two Australian RU clubs located in Sydney's northern suburbs. All participants recruited played in senior grades and were male aged 18 years or over (mean age: 24.1 years ± 5.7 years). Participants were recruited pre-season. Data collection and player monitoring was completed by the rugby clubs' sports medicine personnel after a training period to standardise all assessments and recording methods. The inclusion criterion for the club medical personnel was: a relevant tertiary health related qualification such as doctor, physiotherapist or chiropractor. Data collectors attended all training sessions and matches in an attempt not to miss the injuries of interest during the observation period.

Neck injury definition was all encompassing[19]. Neck injury was defined as any injury to the neck region which was sustained as a result of participation in rugby union which caused a reduction in the amount or level of sports activity, or need for advice or treatment, or adverse social or economic effects[7,20]. A visual pain diagram supplied in the data collection questionnaire oriented data collectors as to the region inclusive for neck injury. The data collection questionnaire was a modified version of the Rugby Union Injury Report Form for Games and Training (RUIRF)[21]. It was modified to collect specific details of neck injury such as symptoms of neck injury, visual range of motion findings, other physical orthopedic findings plus techniques, modalities and advice used in the management of neck injury. Details on mechanism of injury were gathered by data collectors through athlete interview immediately following the inciting injury event. The RUIRF includes the Orchard Sports Injury Classification System (version 8),[22] further adding details of injury type to collected data. The injury diagnosis was made by the clubs medical personal (data collectors) based on clinical examination findings. Incidence was reported as the number of neck injuries per 1000 player-hours. Attempts were made to measure actual exposure[7] time by including training time in exposure time. The formula: Incidence = 1000 × (number of neck injuries per season)/(1.33 games + trainings hours) (number of participants) was used in the calculation of incidence. Severity of injury was reported as the total number of weeks missed from play[23,24]. Severity was arbitrarily grouped as minor (less than one week lost from play), mild (1-2 weeks lost from play), moderate (2-3 weeks lost from play) and severe (3 + weeks lost from play).

Analysis of game versus training risk and injury rate required fitting a Poisson regression model. This analysis was undertaken using the statistical package GenStat. Associations between outcome measures and player position, phase of play, aetiology and injury type have been described by means of cross tabulation. Associations with injury severity were mostly conducted using ordinal logistic regression models. These analyses were undertaken using the statistical package Minitab. $P < 0.05$ was considered statistically significant, although values in the range $0.05 < P < 0.10$ are worth commenting on for potential associations. Where appropriate, 95% confidence intervals (95%CI) were calculated. For incidence, these have been based on Poisson and binomial distribution assumptions for incidence and percentage results respectively. They were obtained using the standard errors of parameter estimates from GenStat's generalised linear model procedure.

Results

The cohort consisted of 262 participants who were recruited over two seasons. A total of 90 (eight recurrent) neck injuries were recorded which affected 74 players. Exposure time for the cohort was calculated at 12863.8 hours of match time and 18280 hours of training totalling 31143.8 hours of play. Incidence of neck injury in this cohort was calculated to be 2.9 injuries/1000 player-hours (95%CI: 2.3, 3.6) with a recurrence incidence of 0.26 repeat injuries/1000 player-hours (95%CI: 0.13, 0.52). Of the neck injuries requiring medical attention on field, 46.5% resulted in the player retiring injured from play. The odds ratio for retiring versus return to play as a risk factor of injury severity was 7.01 (95%CI: 2.31, 21.29). Therefore players who retired injured were 7.01 times more likely to have a more time off compared to a player who did return to play. In regards to time lost from play 69.3% of neck injuries required no additional weeks off from play, 17% missed one additional week of play, 6.8% of injured players missed two weeks from play and 6.8% of players missed three or more weeks from play. Two neck injuries were unable to be tracked and had unknown severity. As expected players who returned to play tended to have far less subsequent time off play ($P = 0.000$). A single spinous process avulsion fracture not affecting the lamina loosely matched the definition of serious cervical spine injury during this study. No fatal or non-fatal catastrophic injuries were reported during the study period.

Game versus training

Game injuries at 85.6% (N = 77) of total neck injuries were more frequent than training injuries which accounted for 14.4% of neck injuries. The incidence of neck injury due to match play was 5.99 injuries/1000 player-hours (95%CI: 4.77, 7.52) while training incidence was 0.71 injuries/1000 player-hours (95%CI: 0.41, 1.24). The incidence of neck injury was significantly higher in games than in training ($P < 0.001$), with the risk being 8.4 times greater (95%CI: 4.6, 15.3). A similar severity pattern was apparent between game and training neck injuries (Table 1). There was no detectable association between game versus training and neck injury severity (P = 0.50).

Position

The hooker, front row and back row positions demonstrated the highest number of neck injuries in this cohort, while the fullback and wingers followed by the five-eighth and midfield backs demonstrated the lowest number of neck injuries (Table 2). Whilst only forwards fell into the category of the most severe injuries (3 + weeks lost from play), there was no detectable association between position of play and neck injury severity ($P = 0.88$) (Table 3).

Further analysis was performed on groups of player positions. In this cohort 78.9% of neck injuries affected the forwards and 21.1% of injuries were sustained by backs. There was a high proportion of injuries in the forward positions. From the cross tabulation, there was no apparent difference in forward versus back position and neck injury severity (Table 3). This was further supported by the ordinal logistic regression analysis, which confirms there is no difference in time off for those that are injured and forward versus back position ($P = 0.36$). Further tabulation of player position into groups of front row, second row, back row, scrum halves, inside backs and outside backs was included (Table 2). There was an uneven distribution of injuries across this grouping with an apparent excess in the back and front row positions. Again, the expected number can be calculated in proportion to the number of player positions within each grouping. This analysis confirms the significant differences in injury frequency across the player positions ($P = 0.000$). The contribution to the chi-square statistic indicates the excess of the front row injuries, but also the relatively low rate for the outside backs (wingers and fullback). However, there was no significant difference in injury severity across this grouping, as indicted by the cross tabulation, and the results of an ordinal logistic regression analysis ($P = 0.68$). Finally comparison was made between injury frequency of front row and back row players. In this cohort there was no significant difference in the neck injury frequency of back row and front row ($P = 0.30$). Consequently, there was no significant difference in neck injury severity between these two groups ($P = 0.42$).

Phase of play

The tackle phase of play demonstrated the greatest number of neck injuries in this cohort followed by the scrum and ruck (Table 4). The tackle phase and scrum demonstrated the most severe (3 + weeks lost from play) neck injuries however, there was no detectable association between phase of play and neck injury severity ($P = 0.27$) (Table 5).

Table 1: Incidence and severity of game and training neck injuries

Severity	Game	Training	All
Minor	N = 51 3.96 (CI: 2.95, 5.21) 68.0%	N = 10 0.55 (CI: 0.26, 1.01) 76.9%	N = 61 1.96 (CI: 1.50, 2.52)
Mild	N = 13 1.01 (CI: 0.54, 1.73) 17.3%	N = 2 0.11 (CI: 0.01, 0.40) 15.4%	N = 15 0.48 (CI: 0.27, 0.79)
Moderate	N = 6 0.47 (CI: 0.17, 1.02) 8.0%	N = 0 0.00 0.0%	N = 6 0.19 (CI: 0.07, 0.42)
Severe	N = 5 0.39 (CI: 0.13, 0.91) 6.7%	N = 1 0.06 (CI: 0.00, 0.30) 7.7%	N = 6 0.19 (CI: 0.07, 0.42)

Game incidence/1000 game player-hours (95% CI)
Training incidence/1000 training player-hours (95% CI)
All incidence/1000 player-hours (95% CI)

Table 2: Incidence of neck injury as a factor of player position

Position of play	Count (N)	Incidence/1000 player hours	Percent %
Forwards	(71)	4.27 (CI: 3.34, 5.39)	78.9%
Back Row	(25)	4.01 (CI: 2.60, 5.92)	27.8%
LF	(8)	3.85 (CI: 1.66, 7.59)	8.9%
8	(8)	3.85 (CI: 1.66, 7.59)	8.9%
RF	(9)	4.33 (CI: 1.98, 8.23)	10.0%
Second Row	(12)	2.89 (CI: 1.49, 5.05)	13.3%
LL	(8)	3.85 (CI: 1.66, 7.59)	8.9%
RL	(4)	1.93 (CI: 0.52, 4.93)	4.4%
Front Row	(34)	5.46 (CI: 3.78, 7.63)	37.8%
LHP	(9)	4.33 (CI: 1.98, 8.23)	10.0%
H	(15)	7.22 (CI: 4.04, 11.92)	16.7%
THP	(10)	4.82 (CI: 2.31, 8.86)	11.1%
Backs	(19)	1.31 (CI: 0.79, 2.04)	21.1%
Inside Backs	(6)	1.44 (CI: 0.53, 3.14)	6.7%
IC	(3)	1.44 (CI: 0.30, 4.22)	3.3%
OC	(3)	1.44 (CI: 0.30, 4.22)	3.3%
Outside Backs	(4)	0.64 (CI: 0.17, 1.64)	4.4%
LW	(1)	0.48 (CI: 0.01, 2.68)	1.1%
RW	(2)	0.96 (CI: 0.12, 3.48)	2.2%
FB	(1)	0.48 (CI: 0.01, 2.68)	1.1%
Scrum Halves	(9)	2.17 (CI: 0.99, 4.11)	10.0%
HB	(7)	3.37 (CI: 1.36, 6.95)	7.8%
5/8	(2)	0.96 (CI: 0.12, 3.48)	2.2%

Table 3: Severity of neck injury as a factor of grouped player position

Severity	Back Row (3)	Front Row (3)	Inside Backs (2)	Outside Backs (3)	Scrum Halves (2)	Second Row (2)	Backs (7)	Forwards (8)
Minor	N = 17	N = 22	N = 4	N = 2	N = 8	N = 8	N = 14	N = 47
	2.73 (CI: 1.59, 4.37)	3.53 (CI: 2.21, 5.35)	0.96 (CI: 0.26, 2.47)	0.32 (CI: 0.04, 1.16)	1.93 (CI: 0.83, 3.80)	1.93 (CI: 0.83, 3.80)	0.96 (CI: 0.53, 1.62)	2.83 (CI: 2.08, 2.76)
	70.8%	64.7%	66.7%	66.7%	88.9%	66.7%	77.8%	67.1%
Mild	N = 6	N = 5	N = 0	N = 1	N = 1	N = 2	N = 2	N = 13
	0.96 (CI: 0.35, 2.10)	0.80 (CI: 0.26, 1.87)	0.00	0.16 (CI: 0.00, 0.89)	0.16 (CI: 0.00, 0.89)	0.48 (CI: 0.06, 1.74)	0.14 (CI: 0.02, 0.50)	0.78 (CI: 0.42, 1.34)
	25.0%	14.7%	0.0%	33.3%	11.1%	16.7%	11.1%	18.6%
Moderate	N = 0	N = 3	N = 2	N = 0	N = 0	N = 1	N = 2	N = 4
	0.00	0.48 (CI: 0.10, 1.41)	0.48 (CI: 0.06, 1.74)	0.00	0.00	0.16 (CI: 0.00, 0.89)	0.14 (CI: 0.02, 0.50)	0.24 (CI: 0.07, 0.62)
	0.0%	8.8%	33.3%	0.0%	0.0%	8.3%	11.1%	5.7%
Severe	N = 1	N = 4	N = 0	N = 0	N = 0	N = 1	N = 0	N = 6
	0.16 (CI: 0.00, 0.89)	0.62 (CI: 0.17, 1.64)	0.00	0.00	0.00	0.16 (CI: 0.00, 0.89)	0.00	0.36 (CI: 0.13, 0.79)
	4.2%	11.7%	0.0	0.0%	0.0%	8.3%	0.0%	8.6%

Neck injury count
Incidence/1000 player-hours (95% CI)
Percent

Table 4: Incidence of neck injury as a factor of phase of play and player position

Phase of play	Back Row	Front Row	Inside Back	Outside Back	Scrum Halves	Second Row	All
Collision	N = 0	N = 0	N = 1	N = 0	N = 0	N = 0	N = 1
	0.00	0.00	0.24 (CI: 0.01, 1.34)	0.00	0.00	0.00	0.03 (CI: 0.00, 0.18)
	0.0%	0.0%	16.7%	0.0%	0.0%	0.0%	1.2%
Lineout	N = 0	N = 0	N = 0	N = 0	N = 0	N = 1	N = 1
	0.00	0.00	0.00	0.00	0.00	0.16 (CI: 0.00, 0.89)	0.03 (CI: 0.00, 0.18)
	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%	1.2%
Maul	N = 2	N = 2	N = 0	N = 0	N = 0	N = 2	N = 6
	0.32 (CI: 0.04, 1.16)	0.32 (CI: 0.04, 1.16)	0.00	0.00	0.00	0.48 (CI: 0.06, 1.74)	0.19 (CI: 0.07, 0.42)
	8.3%	6.3%	0.0%	0.0%	0.0%	16.7%	6.9%
Ruck	N = 5	N = 5	N = 1	N = 1	N = 4	N = 4	N = 20
	0.80 (CI: 0.26, 1.87)	0.80 (CI: 0.26, 1.87)	0.24 (CI: 0.01, 1.34)	0.16 (CI: 0.00, 0.89)	0.96 (CI: 0.26, 2.47)	0.96 (CI: 0.26, 2.47)	0.64 (CI: 0.32, 0.99)
	20.8%	15.6%	16.7%	25.0%	44.4%	33.3%	23.0%
Scrum	N = 2	N = 20	N = 0	N = 0	N = 0	N = 0	N = 22
	0.32 (CI: 0.04, 1.16)	3.21 (CI: 1.96, 4.96)	0.00	0.00	0.00	0.00	0.71 (CI: 0.44, 1.07)
	8.3%	62.5%	0.0%	0.0%	0.0%	0.0%	25.3%
Tackle	N = 15	N = 5	N = 4	N = 3	N = 5	N = 5	N = 37
	2.41 (CI: 1.35, 3.97)	0.80 (CI: 0.26, 1.87)	0.96 (CI: 0.26, 2.47)	0.48 (CI: 0.10, 1.04	1.20 (CI: 0.39, 2.81)	1.20 (CI: 0.39, 2.81)	1.19 (CI: 0.84, 1.64)
	62.5%	15.6%	66.7%	75.0%	55.6%	41.7%	42.5%

Neck injury count
Incidence/1000 player-hours (95% CI)
Percent

Table 5: Severity (count) of neck injury as a factor of phase of play

Severity	Collision	Lineout	Maul	Ruck	Scrum	Tackle
Minor	N = 1	N = 1	N = 5	N = 17	N = 13	N = 23
	0.03 (CI: 0.00. 0.18)	0.03 (CI: 0.00. 0.18)	0.16 (CI: 0.05, 0.37)	0.55 (CI: 0.31, 0.87)	0.42 (CI: 0.22, 0.71)	0.74 (CI: 0.47, 1.11)
	100.0%	100.0%	83.3%	85.0%	59.1%	65.7%
Mild	N = 0	N = 0	N = 0	N = 2	N = 3	N = 8
	0.00	0.00	0.00	0.02 (CI: 0.01, 0.23)	0.10 (CI: 0.02, 0.28)	0.26 (CI: 0.11, 0.51)
	0.0%	0.0%	0.0%	10.0%	13.6%	22.9%
Moderate	N = 0	N = 0	N = 1	N = 1	N = 3	N = 1
	0.00	0.00	0.03 (CI: 0.00. 0.18)	0.03 (CI: 0.00. 0.18)	0.10 (CI: 0.02, 0.28)	0.03 (CI: 0.00. 0.18)
	0.0%	0.0%	16.7%	5.0%	13.6%	2.9%
Severe	N = 0	N = 0	N = 0	N = 0	N = 3	N = 3
	0.00	0.00	0.00	0.00	0.10 (CI: 0.02, 0.28)	0.10 (CI: 0.02, 0.28)
	0.0%	0.0%	0.0%	0.0%	13.6%	8.6%

Neck injury count
Incidence/1000 player-hours (95% CI)
Percent

Further analysis compared phase of play with player position for correlation. However, the counts were too low to make meaningful tests of associations. To overcome this, some of the less frequent categories were removed, namely collision, lineout, maul (phase of play) and inside backs, outside backs and scrum halves (player position). The reduced table then facilitated a chi-square test of association. The overall level of significance for association is $P = 0.000$, indicating a strong association. Comparing the observed and expected frequencies, it is evident that in the back row, there is an excess of tackle injuries, and a deficit of scrum injuries, whereas in the front row, this pattern is reversed. With regards to injury severity, it was found through tabulation of ordinal logistic regression that neither position nor phase of play influence injury severity ($P = 0.30$).

Mechanism of injury

There were up to four injury mechanisms listed per neck injury suggesting force directions that cause neck injury are seldom uniplanar. The following table shows the absolute numbers, and also as a percentage (relative to the total number of injuries, i.e. 90) (Table 6).

As multiple mechanisms of injury were recorded the mechanism was coded into the presence/absence of each of the mechanisms; compression, extension, flexion, rotation, and side bend. A separate analysis was then undertaken for each of these mechanisms. The following table shows the number that reported each specific mechanism, shown for each 'severity' group (Table 7).

There is some evidence of a weak association between time lost and presence of a compression mechanism injury ($P = 0.073$), with more time lost when this mechanism occurs, compared to when it did not. The odds ratio for compression as a risk factor was 2.62 (95% CI: 0.89-7.73) therefore players reporting this injury mechanism are 2.62 times more likely to have time lost from play compared with a player who did not report this mechanism. No other mechanism was associated with injury severity (all $P > 0.5$).

Orchard Sports Injury Classification (OSICS-8)

Cervical facet joint injury was the most frequently recorded (42%) classification of neck injury, followed by brachial plexus/cervical nerve root injury (stinger/

Table 6: Aetiology and incidence of neck injury

Mechanism	Count	%
Compression	49	54%
Flexion	38	42%
Rotation	20	22%
Side bend	31	34%
Unknown	6	7%

Table 7: Aetiology and severity of neck injury

Severity	Compression	Extension	Flexion	Rotation	Side bend	All
Minor	32	7	27	13	21	58
Mild	12	1	5	2	6	13
Moderate	4	1	2	1	3	5
Severe	3	1	4	3	1	6
All	51	10	38	19	31	82

Note that the sum of the counts will exceed the 'All' column, due to multiple mechanisms reported per injured player.
Neck injury count

burner). At face value these injuries appeared to be associated with the highest time lost from play (Table 8). However, more formal analysis revealed no detectable association between OSICS-8 and neck injury severity ($P = 0.35$). Further comparison was made between Orchard sports injury classification with phase of play. The overall cross tabulation between phase of play grouping and OSICS-8 (Table 9) indicates some low frequencies, preventing an overall analysis of association. However, a sub set of data involving only brachial plexus/cervical nerve root injury (stinger/burner) and cervical facet joint injury, as well as scrum and tackle was extracted. The association of these low-frequency data was analysed using a Fisher's exact test for a 2 × 2 table. There was no significant relationship between tackle versus scrum and injury type (NP1 versus SN1) ($P = 0.22$). Further on relationship with severity was examined via an ordinal logistic regression to assess the effect of both Orchard sports injury classification (NP1 versus SN1) and phase of play (Scrum versus Tackle). No significant effect of either of these terms on injury severity ($P = 0.30$) was identified in this cohort.

Discussion

To the authors knowledge this is the first prospective study of neck injury in an amateur men's population since the inception of the professional RU era. Via an all inclusive injury definition and calculation of game, training and overall parameters of exposure time, incidence of neck injury in an amateur RU cohort is estimated as: 5.99/1000 match player-hours, 0.71/1000 training player-hours and 2.9/1000 play-hours. Furthermore, a minimum of 50 player weeks was lost from play. An intuitive pattern of neck injury resulted: less severe injuries occurred most frequently and most severe neck injuries occurred least frequently. Aetiology of neck injury in this study was seldom found to be a result of uniplanar neck movement, as several planes of movement were commonly reported per neck injury. The most frequently occurring neck injury type in this population was cervical facet joint injury as assessed by tertiary qualified data collectors.

There are limitations in studying amateur sporting populations, which may not be as apparent in the professional arena. It is important to reliably identify athletic exposure[25]. In this study population the position of play sometimes varied throughout the season. For example, front row players sometimes played games in the centre position, which limits the accuracy of incidence by position of play. As such cautious estimation has been reported on player position data. Methods of assessing mechanism of injury and sports injury type pose a challenge in sports injury epidemiology. The ability of injured athletes to comprehend and recall what actually took place when they were injured is debateable, and a limitation of this study. This is due to the speed at which injury events occur and the propensity for neck injury to be associated with head injury and disorientation[26]. Furthermore the ability of a clinician to describe a tissue injury diagnosis through subjective examination is limited[27]. In this study more objective criteria such as ultrasound and magnetic resonance imaging were precluded due to costs and practicality.

Paucity in the literature of similar population with similar injury definition and study design limits comparison of these results with parallel studies. Since the commencement of this study consensus has been achieved on injury definitions and data collection procedures for studies of injuries in RU[28]. This is crucial for meaningful comparison of studies in the future.

Recent estimation of match play neck injury incidence in professional RU populations was reported to range between 4.2 (95%CI: 2.1, 8.3) and 6.46 (95%CI: 5.31, 7.86)/1000 player-hours[29,30]. The incidence of neck injury in this study fell within this range of professional

Table 8: Injury type incidence and severity

Severity	NG1	NJ1	NL1	NM1	NN1	NP1	NZ1	SN1	NP1 SN1
Minor	N = 0	N = 1	N = 7	N = 11	N = 1	N = 27	N = 8	N = 6	
	0.00	0.03 (CI: 0.00, 0.18)	0.22 (CI: 0.09, 0.46)	0.35 (CI: 0.18, 0.63)	0.03 (CI: 0.00, 0.18)	0.87 (CI: 0.57, 1.26)	0.26 (CI: 0.11, 0.51)	0.19 (CI: 0.07, 0.42)	
	0.0%	100.0%	58.3%	84.6%	50.0%	71.1%	88.9%	46.2%	
Mild	N = 1	N = 0	N = 3	N = 1	N = 1	N = 6	N = 0	N = 3	
	0.03 (CI: 0.00, 0.18)	0.00	0.10 (CI: 0.02, 0.28)	0.03 (CI: 0.00, 0.18)	0.03 (CI: 0.00, 0.18)	0.19 (CI: 0.07, 0.42)	0.00	0.10 (CI: 0.02, 0.28)	
	100.0%	0.0%	25.0%	7.7%	50.0%	15.8%	0.0%	23.1%	
Moderate	N = 0	N = 0	N = 1	N = 1	N = 0	N = 2	N = 1	N = 1	
	0.00	0.00	0.03 (CI: 0.00, 0.18)	0.03 (CI: 0.00, 0.18)	0.00	0.06 (CI: 0.01, 0.23)	0.03 (CI: 0.00, 0.18)	0.03 (CI: 0.00, 0.18)	
	0.0%	0.0%	8.3%	7.7%	0.0%	5.3%	11.1%	7.7%	
Severe	N = 0	N = 0	N = 1	N = 0	N = 0	N = 3	N = 0	N = 2	
	0.00	0.00	0.03 (CI: 0.00, 0.18)	0.00	0.00	0.10 (CI: 0.02, 0.28)	0.00	0.06 (CI: 0.01, 0.23)	
	0.0%	0.0%	8.3%	0.0%	0.0%	7.9%	0.0%	13.4%	
All	N = 1	N = 1	N = 12(1)	N = 13	N = 2(2)	N = 38(3)	N = 9	N = 13*(2)	N = 1*
	0.03 (CI: 0.00, 0.18)	0.03 (CI: 0.00, 0.18)	0.38 (CI: 0.20, 0.67)	0.42 (CI: 0.22, 0.71)	0.06 (CI: 0.01, 0.23)	1.22 (CI: 0.86, 1.67)	0.28 (CI: 0.13, 0.55)	0.42 (CI: 0.22, 0.71)	0.03 (CI: 0.00, 0.18)
	1.1%	1.1%	13.3%	13.3%	2.2%	42.2%	10.0%	14.4%	1.1%

*Two injuries with unknown severity
INJURY TYPE ABBREVIATION
NG1: Avulsion fracture (spinous process) of the cervical spine, NJ1: Whiplash/neck sprain, NL1: Neck ligament injury, NM1: Neck muscle strain, NM1 (Contusion): Neck muscle contusion, NN1: Cervical nerve root compression/stretch, NP1: Cervical facet joint pain, NZ1: Neck pain undiagnosed, SN1: Brachial plexus traction injury/stinger/burner
Neck injury count (recurrent neck injury count)
Incidence/1000 player-hours (95% CI)
Percent

Table 9: Injury type count as a factor of phase of play

Injury type	Ruck	Scrum	Tackle
NG1	N = 0 0.00 0.0%	N = 0 0.00 0.0%	N = 0 0.00 0.0%
NJ1	N = 0 0.00 0.0%	N = 0 0.00 0.0%	N = 0 0.00 0.0%
NL1	N = 3 0.10 (CI: 0.02, 0.28) 15.0%	N = 5 0.16 (CI: 0.05, 0.37) 22.7%	N = 4 0.13 (CI: 0.03, 0.33) 10.8%
NM1	N = 3 0.10 (CI: 0.02, 0.28) 15.0%	N = 4 0.13 (CI: 0.03, 0.33) 18.2%	N = 2 0.06 (CI: 0.01, 0.23) 5.4%
NN1	N = 0 0.00 0.0%	N = 0 0.00 0.0%	N = 2 0.06 (CI: 0.01, 0.23) 5.4%
NP1	N = 11 0.35 (CI: 0.18, 0.63) 55.0%	N = 9 0.29 (CI: 0.13, 0.55) 40.9%	N = 17 0.55 (CI: 0.32, 0.87) 45.9%
NZ1	N = 2 0.06 (CI: 0.01, 0.23) 10.0%	N = 3 0.10 (CI: 0.02, 0.28) 13.6%	N = 2 0.06 (CI: 0.01, 0.23) 5.4%
SN1	N = 1 0.03 (CI: 0.00, 0.18) 5.0%	N = 1 0.03 (CI: 0.00, 0.18) 4.5%	N = 10 0.32 (CI: 0.15, 0.59) 27.0%

Injury type abbreviation
NG1: Avulsion fracture (spinous process) of the cervical spine, NJ1: Whiplash/neck sprain, NL1: Neck ligament injury, NM1: Neck muscle strain, NN1: Cervical nerve root compression/stretch, NP1: Cervical facet joint pain, NZ1: Neck pain undiagnosed, SN1: Brachial plexus traction injury/ stinger/burner
Neck injury count
Incidence/1000 player-hours (95% CI)
Percent

RU reports. This finding appears to conflict with the trend noted elsewhere,[18] that increasing injury incidence is related with higher levels of play. Comparison of studies with disparate injury definitions must be undertaken with caution. Further studies on amateur populations are required to identify if neck injury incidence in amateurs mirrors that of professional RU populations.

This and other prospective cohort studies in RU[29-33] have found a higher incidence of neck injury match play compared to training. Similar to all studies is the greater exposure time to training than match play. Brooks et al[33] considers the contact phases of training very high risk while non-contact phase of training to be very low risk. Suggested reasons for a high injury rate of match play injury are associated with game intensity and player fatigue,[14] they include; 1) Increased 'ball in play' time in match situations, as seen in the professional era, therefore increased exposure to contact situations;[32] 2) In part training focus may change from skills to conditioning;[32] 3) There may have been a de-emphasis of the contact phase of skill training[32]. Further to injury rate, severity of game versus training neck injury appears similar to other studies[29-33] with a similar average[29] severity.

Recent evaluation of the tackle phase of rugby union suggest ball carriers[34,35] and tacklers[34] are at risk of head and neck injury. This study found the back row players to be particularly susceptible to tackle related neck injury. Indeed data observed by Quarrie and Hopkins[35] and Fuller et al[34] suggest the back row players have a high exposure to tackle events which may be reflected in this study's findings. In addition, this and other[36-38] studies found neck injury occurred in the forwards more frequently than the backs. The front row players, namely the hookers, were most frequently affected by neck injury through their role in the scrum phase of play. The high risk component of this phase is engagement and subsequent collapse as a result of improper engagement[1]. Ongoing vigilance towards player safety is required in scrums.

The tackle phase of play in this study was found to demonstrate the greatest number of neck injuries, followed by the scrum and ruck. A similar trend has been identified elsewhere for all injury types in amateur RU[9,33,39]. Recently Fuller et al[40] commented on the relative propensity for contact events to cause injury in RU. This was achieved by adjusting the injury probability to represent the contact event exposure time. They found relative to exposure, collisions were 70% more likely and scrums 60% more likely to result in an injury than a tackle[40]. Such adjustment for exposure time per contact event was not accounted for in this study and acknowledged as a limitation.

Compression was found to be the most frequently described mechanism of neck injury in amateur men, followed by flexion then side-bend of the neck. Indeed these results support the concept of Winkelstein and Myers,[41] who suggest uni-planar compression force is too simplistic. Compressive and shear forces are generated during a tackle situation by the combined effort of neck, head and shoulder areas[42]. Cervical compression via a blow to the vertex of the head has previously been identified as a high risk mechanism associated with scrum impact[43] and tackles[44,45]. When neck compression was a factor in this study, the severity of neck injury appeared to be greater. Indeed, more sinister injuries in athletes such as burst fracture, fracture dislocation, lamina fracture and collapsed vertebra have been associated with the mechanism of axial compression with or without rotation or hyper-flexion[46].

The OSCIS-8 is considered the preferred coding system for sports medicine research[47] which has more recently been superseded by a 10^{th} version[48]. Facet joint and nerve root/brachial plexus injuries have been previously identified as the most common neck injury type in professional RU[29] as in this study. Conversely, no significant correlation was found between type of neck injury and severity in this study. Additionally correlations between phases of play and neck injury type, could not be found. Therefore disparity exists between the findings of Fuller et al[29] that scrummaging had a higher frequency of facet mediated problems and the tackle phase had more cervical nerve root injury type[29]. A larger data pool may identify a relationship between phase of play and neck injury type in an amateur rugby union population.

Conclusions

Severe neck injuries still occasionally occur in RU, particularly at the amateur level[49]. Stakeholders such as coaches, policy makers and sports medicine personnel should seek epidemiological data when evaluating the risk associated with the practice of RU football. Sound prevention and management strategies targeted at neck injury in RU require current information obtained through best available methods. The results of this study provide a yardstick for the incidence, severity, aetiology and type for future neck injury surveillance in Australian men's amateur RU.

Competing interests
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Authors' contributions
MSS conceived the study, participated in the study design, collected baseline data, trained data collector, collected data from games and trainings of LRU, drafted and edited the manuscript. HPP conceived the study, participated in the study design, helped to draft and edit the manuscript. RB conceived the study, participated in the study design, helped to draft and edit the manuscript. All authors read and approved the manuscript.

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- Concept and design of the research: MSS 70%, HPP 15%, RB 15%
- Data retrieval and preparation of the manuscript content: MSS 90%, HPP 5%, RB 5%
- Critical review: MSS 61%, HPP 13%, RB 13%, SW 13%
- Writing: MSS 80%, HPP 5%, RB 5%, SW 10%

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Risk factors for neck injury in men's amateur Rugby Union: a prospective cohort study

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INDEX TERMS: MeSH: epidemiology, rugby, football, neck, athletic injury.

Abstract

Background: Identifying risk factors specific to sports injury is an important step in the prevention of neck injury. Several risk factors for neck injury in Rugby Union have been proposed. To date limited scientific rigor has been applied when identifying these risk factors.

Method: Data was collected from a cohort of 262 participants from two Australian amateur men's Rugby Union clubs in a prospective cohort study. Baseline data was collected pre-season via a self-reported questionnaire and a physical assessment that included neck range of motion screening. The risk factors evaluated were: time of game, time of season, legal versus illegal play, grade of play, age of player, player experience, stage of career, ethnic origin, occupation, alcohol consumption, pre-season preparation, type of preseason preparation, previous and current neck injury. A modified version of the Rugby Union Injury Report Form for Games and Training was used by the clubs sports medicine personnel for data collection.

Results: There was a strong association between the incidence of neck injury and pain reported during the pre-season neck active range of motion screening ($p = 0.002$). None of the other proposed risk factors were associated with an increased incidence or severity of neck injury.

Conclusion: The screening of risk factors by amateur Rugby Union clubs may reduce the incidence of neck injury in rugby. Further larger studies are required to confirm the associations found in this study.

Background

The prevention of sports injury first requires identifying the incidence and severity of the sports injury [1]. The second step is to establish if there is a relationship between a potential risk factor and the sports injury based on probability and consequence statistics [2].

Analytical studies such as prospective cohort and interventional studies enable the evaluation of relationships between possible risk factors and injuries [3]. Descriptive studies such as case reports and cross sectional/correlation studies may identify associations between the incidence of injury and risk factors, but cannot confirm that causal relationships exist [3].

Neck injury in Rugby Union (RU) range from relatively benign isolated muscle strains [4-6] to sinister complex spinal cord injury [7-10]. There is very little analytical data to confirm or refute causal relationships between possible risk factors and neck injury in RU [11]. A few prospective cohort studies in RU that have focused specifically on neck injury have observed professional [12] or junior populations [13]. There appears to be a lack of prospective neck injury data available on amateur populations, especially in recent times.

Several risk factors for neck injury in RU have been proposed [14]. Extrinsic risks that relate to the game itself such as: the laws of the game [9, 15-21], player position [8-9, 22] and match participation [20-21, 23-26] have been well researched [11].

Conversely intrinsic risk factors such as neck strength, have been assumed to be important without the support of direct evidence [27-36].

The objective of this study was to identify possible risk factors that increase the incidence and severity of neck injuries in men's amateur RU using a 2-year prospective cohort study.

Methods

Ethics approval was obtained from the Ethics Review Committee (Human Research), Macquarie University, Sydney, Australia (reference number: HE24FEB2006-M04460). Written prior approval was granted by senior club representatives and sports medicine personnel. Participants gave written consent to participate in the study.

A prospective cohort study was carried out through the 2006 and 2007 RU seasons. Participants (n=262) were recruited from two Australian RU clubs located in Sydney's northern suburbs. All participants were male senior grade players, aged between 18 – 59 years (24.1 ± 5.7 years), and registered to play RU during the study period. Their playing experience ranged from 0 - 48 years (12.5 ± 6.3 years). All participants had to be registered at the start of each season, but individual dropouts were not monitored.

Participants completed a self-reported questionnaire and were given a physical assessment at the time of recruitment. The questionnaire gathered information regarding previous and current neck injury, play experience, age and maturity, occupation, current physical preparation, ethnicity and alcohol use. The physical examination consisted of an active cervical spine range of motion (ROM) assessment using visual estimation [37-38], a cervical stability (deep neck flexor endurance) test [39], and a cervical spine isometric pre-participation strength assessment [40]. The baseline physical assessment was conducted by a registered chiropractor. The active cervical ROM assessment required each participant to move their neck through the full range of flexion/extension, bilateral side-bend, and bilateral rotation. The normal limits of cervical mobility, as described Magee [37], were provided for the examiners reference. In the event that a player displayed reduced ROM or reported pain/discomfort during the ROM, a repeat assessment was performed to confirm the finding. The reduced or painful neck ROM was reported on the players baseline assessment form. The cervical stability test involved the supine player holding their head a finger width off a portable table while the examiner monitored chin poke, head raise or inability to hold the head off the table in the initial four seconds. The cervical spine strength assessment was conducted with the player balancing his body at a 45º angle to the wall. The ability of the cervical spine to hold the body weight in this position is an established test of cervical spine strength [40].

The competition season for this cohort began in April and ended in September. The season was divided into three sections; the first third (April – May); the second third (June – July); and the last third (August – September) in which the finals are played. The time neck injury occurred in a match was recorded as first half, second half or time on (extra time). The baseline questionnaire collected information pertaining to a player’s grade of play, age, and experience and these were placed into groupings for statistical assessment. Players were graded from 1st - 4th, with first grade players considered the highest level of play. Players were also age-grouped (18-20 years, 21-24 years, 25-28 years, 29-34 years and 35+ years), and grouped according to years of experience (00 - 04, 05 - 09, 10 - 14, 15 - 19 and 20+ years). Players were asked to comment on what stage in their playing career they perceived themselves to be in, by choosing from a list of comments such as: ‘I don’t believe I have yet reached my playing potential’, ‘I am currently playing RU at the peak of my potential’ or ‘I have already passed my playing peak’. Player ethnicity was recorded as it has been reported that certain ethnic groups are at higher risk for neck injury in RU [14, 41]. Players were asked to estimate their physical preparation time pre-season in hours per week and also total number of weeks. They were then grouped according to their total number of weeks (000-049, 050-099, 100-149 and 150+ hours). Players specified their pre-season training (weight training, running, boxing, rowing, cycling, ball handling, and ‘other’). Players were asked if they had injured their neck during the pre-season as a result of playing RU, and were asked if they currently had a neck injury.

Data collection and player monitoring was completed by the rugby clubs trained sports medicine personnel, all of whom had a relevant tertiary health related qualification such as physiotherapy or chiropractic. Data collectors attended all training sessions and matches.

Injury data was collected using a modified version of the Rugby Union Injury Report Form for Games and Training (RUIRF). Neck injury was defined as encompassing all injury to the neck region sustained as a result of participation in RU, resulting in either a reduction in the amount and/or level of sports activity, or the need for advice or treatment, or leading to adverse social or economic effects [1, 42-43]. A visual pain diagram was used to record the specific neck region of injury. Two outcome measures were recorded: the incidence and the severity of the neck injury. The injury rate was reported as the number of neck injuries per 1000 player hours. The formula, after van Mechelen [1], Hodgson [42], Quarrie et al. [44], and King et al. [45], was:

$$\text{Incidence} = 1000 \times \frac{(\text{number of neck injuries per season})}{(1.33\ \text{games} + \text{training hours})(\text{number of participants})}$$

Similar to the methods used by McMannus and Cross [46], Targett [47] and Carson et al. [5], severity of injury was reported as the total number of weeks missed from play, and results were statistically grouped as minor (less than one week), mild (1-2 weeks), moderate (2-3 weeks) and severe (3+ weeks).

Statistics

Analysis of risk and the incidence of injury were measured by cross tabulation and by fitting Poisson regression models, with an offset (i.e. scaling factor) to take into account the number of player-hours in each of the risk sets. Associations between proposed risk factors and injury severity were analysed using ordinal logistic regression models. Statistical significance was set at $p < 0.05$ although values in the range $0.05 < P < 0.10$ were considered in some instances [48]. Where appropriate, 95% confidence intervals (95% CIs) were calculated. Incidence has been based on Poisson regression, and percentage results on binomial distribution assumptions, obtained using the standard errors of parameter estimates from generalised linear modelling. Chi-square (χ^2) analysis tests for association was performed between the groupings of years of experiences and the incidence of injury. Chi-square tests were performed for measuring the association between deep neck flexor endurance and the risk of neck injury.

Results

Incidence and severity

A total of 90 neck injuries were recorded which affected 74 of the players recruited. Exposure time for the cohort was calculated at 12 860 hours of match time and 18 280 hours of training totalling 31 140 hours of play. The incidence of neck injury in this cohort was 5.99 neck injuries /1000 match-hours (95% CI: 4.77, 7.52) and 0.71 neck injuries /1000 training-hours (95% CI: 0.41, 1.24). In terms of severity, 69.3% of neck injuries were classed as minor (n=61), 17% as mild (n=15), 6.8% as moderate (n=6) and 6.8% as severe (n=6). Two neck injuries had unknown severity as injury follow-up was not possible. Further reporting of neck injury aetiology and type in this cohort has been reported elsewhere [49].

Proposed risk factors

Second half game neck injuries were more frequent than first half injuries, with no neck injuries reported in the time on period (Table 1). There was no association between time of play and neck injury severity ($p = 0.74$). The lowest numbers of neck injuries were observed in the last third of the season (Table 1). There was no association between time of season and neck injury severity ($p = 0.75$).

Table 4.2.1
Incidence & severity of neck injury as per time of game and time of season

Severity	Time of Game			Time of season		
	First half	**Second half**	**Time-on**	**First**	**Second**	**Third**
Minor	(15) 1.16 (CI: 0.65, 1.92) 65.2%	(33) 2.57 (CI: 1.77, 3.60) 64.7%	(0) 0.00 0.0%	(28) 0.90 (CI: 0.60, 1.30) 62.3%	(32) 1.03 (CI: 0.70, 1.45) 69.6%	(1) 0.03 (CI: 0.00, 0.18) 33.3%
Mild	(4) 0.31 (CI: 0.08, 0.80) 17.4%	(9) 0.70 (CI: 0.32, 1.33) 17.6%	(0) 0.00 0.0%	(8) 0.26 (CI: 0.11, 0.51) 19.5%	(7) 0.22 (CI: 0.09, 0.46) 13.7%	(0) 0.00 0.0%
Moderate	(1) 0.08 (CI: 0.00, 0.43) 4.3%	(5) 0.39 (CI: 0.13, 0.91) 9.8%	(0) 0.00 0.0%	(2) 0.06 (CI: 0.01, 0.23) 4.9%	(3) 0.10 (CI: 0.02, 0.28) 6.5%	(1) 0.03 (CI: 0.00, 0.18) 33.3%
Severe	(3) 0.23 (CI: 0.05, 0.68) 13.0%	(2) 0.16 (CI: 0.02, 0.56) 3.8%	(0) 0.00 0.0%	(3) 0.10 (CI: 0.02, 0.28) 7.3%	(3) 0.10 (CI: 0.02, 0.28) 6.5%	(0) 0.00 0.0%
All	(23) 1.79 (CI: 1.13, 2.69) 31.1%	(49, *2) 3.96 (CI: 2.95, 5.21) 68.9%	(0) 0.00 0.0%	(41) 1.32 (CI: 0.94, 1.79) 45.6%	(45, *1) 1.48 (CI: 1.08, 1.97) 51.1%	(2, *1) 0.10 (CI: 0.02, 0.28) 3.33%

Count (n)
Incidence /1000 match-hours (95% CIs)
Percent %
* Unknown count

Approximately 2% (n=2) of neck injuries reported was the result of illegal play. Neither illegal injury resulted in time lost from play and were classed as minor. There was no association between legal/illegal play and neck injury severity (p = 0.23). As only two illegal play cases were reported there was not enough statistical power in this sample to detect any possible association.

A similar neck injury count was observed between grades of play (Table 2). There was a very weak trend, with 3rd and 4th grade players having a greater likelihood of having extended time lost from play, however no significant association between grade of play and neck injury severity was detected (p = 0.10).

Table 4.2.2
Incidence and severity of neck injuries as a factor of grade of play

Severity	1st Grade	2nd Grade	3rd	4th
Minor	(19) 82.6%	(19) 73.1%	(12) 50.0%	(11) 68.8%
Mild	(3) 13.0%	(4) 15.4%	(7) 29.2%	(1) 6.3%
Moderate	(1) 4.3%	(2) 7.7%	(2) 8.3%	(1) 6.3%
Severe	(0) 0.0%	(1) 3.8%	(3) 12.5%	(2) 12.5%
All	(23) 25.8%	(26) 29.2%	(24) 27.0%	(15 *1) 18.0%

Count (N)
Percent %
* Unknown count

Analysis found that neck injury incidence was significantly higher in those who reported neck pain with motion pre-season (p = 0.002) (Table 3). Further analysis indicated no association between reported neck pain and injury severity (p = 0.15). There were two identified strength deficit cases and there was no significant difference in the incidence of neck injury for the strength deficit groups (p = 0.91). As there were only two reported strength deficit cases, association with injury severity was not assessed. Further, there was no association between the cervical stability test outcome and neck injury incidence ($p = 0.50$).

Table 4.2.3.
Incidence of neck injury as a factor of neck pain with motion

Reported neck pain	Count	Percent	Exposure (player-hours)	Incidence /1000 player-hours	95% CIs
No	(33)	54.1	19 929	1.66	(1.17, 2.35)
Yes	(28)	45.9	7 402	3.78	(2.59, 5.52)
Total	(61*)				

*29 injuries without perceived neck pain with motion status reported

Analysis of the relationship between the incidence of neck injury and age of player, previous neck injury, perceived stage of career, severity of neck injury and the amount of pre-season training fell between $p = 0.05$ to $p = 0.10$. None of the other measured risk factors were associated with either an increased incidence in neck injury or with the severity of neck injury (Table 4).

Table 4.2.4
Risk factors that showed no statistical association with the incidence of neck injury during play

Proposed risk factor	Incidence association	Severity association
Neck ROM restriction	(p=0.67)	(p=0.58)
Previous neck injury	(p=0.06)	(p=0.28)
Pre-season neck injury	(p=0.37)	(p=0.80)
Age of player	(p=0.07)	(p=0.33)
Experience – years of play	(p=0.17)	(p=0.43)
Perceived stage of career	(p=0.07)	(p=0.62)
Ethnic origin	(p=0.88)	(p=0.52)
Occupation	(p=0.90)	(p=0.75)
Alcohol consumption	(p=0.13)	(p=0.45)
Pre-season training volume	(p=0.38)	(p=0.07)
Pre-season training type	(p=0.32)	(p=0.74)

Discussion

This is, to the best of our knowledge, the first prospective study that has assessed risk factors for neck injury in men's amateur RU. It has uniquely shown that there is a strong association between the incidence of neck injury and pain reported during pre-season ROM assessment. This study is also unique in showing that other factors proposed in the literature as putting the player at risk for neck injury were not associated with an increased incidence of neck injury during the subsequent two seasons, nor were they associated with a higher severity of neck injury. Fuller et al.[12] recently reported that in elite men's RU the incidence of cervical injury increased as the season progressed. This was not shown in this prospective study of amateur RU. But what this study did find is that the incidence of neck injury was at its highest in the second half of the match, which was also found to be the case in professional populations, and has previously been attributed to player fatigue [12, 50-51].

The literature on the risk posed by injuries incurred during previous seasons on the development of neck injury during subsequent play is mixed [44, 52]. In Australian Football a history of previous muscle strain has been reported to be the most important factor for future injury of that muscle group [53]. However our results from this prospective study of amateur RU players do not concur with these findings, but rather are in line with Quarrie et al.[44], who did not find an increased incidence or an increased severity of injury during the season following on from an injury in a previous season of RU.

A lack of fitness or specific training for RU have been suggested as risk factors for neck injury in RU [21]. A previous study of an amateur RU cohort found that more time spent on weekly physical and pre-season training was associated with a higher subsequent in-season incidence of match injuries [54]. The authors suggested this could be due to increased player confidence leading to risky playing behaviour, a "need to win" mentality, or the result of higher rates of preseason injury which limited players during the subsequent training seasons. Residual fatigue from the higher amount of preseason training could also be a factor. In this study, no relationship was found between the time spent in preseason training and the incidence ($P = 0.38$) or severity ($P = 0.07$) of neck injury.

The difference between the findings of this study and others may be due to the likelihood that the risk of neck injury increases when there is an interplay of internal and external risk factors, along with an inciting event [55]. A dynamic, multifactorial model of interpreting sports injury aetiology [55-59] should be considered when evaluating suspected risk factors. In this model, internal risk factors predispose the athlete to injury; the exposure to external risk factors leave the athlete susceptible to injury, and finally an inciting event (injury mechanism) occurs which directly results in the sports injury. However, pain detected with active cervical ROM testing during preseason assessment may be in and of itself a significant risk factor for neck injury, as was found in this study. Brooks et al. [60] suggests players are predisposed to injury because of musculoskeletal or physiological weaknesses and may be more susceptible to injury at the beginning of a season if these weaknesses are not specifically identified and addressed within training programs. Pain reported during ROM testing may be indicative of underlying tissue pathology. Lee et al. [54] found an increased risk of rugby injuries in those players who had become injured during the last season, or who were carrying an injury at the end of the previous season. Potentially improving a player's status from pain reported during pre-season ROM assessment to no pain on pre-season neck ROM testing may provide an effective risk mitigation strategy. The efficacy and efficiency of this proposed preventative strategy [61] should be evaluated through further research.

The differences in findings reported in the literature may also be the result of both a lack of definitive definitions for what constitutes a risk factor or a neck injury, and also for what constitutes the best means by which to measure these variables. These issues need to be addressed before further studies are undertaken [44, 54]. For example, in this study neck strength was assessed using a return to play evaluation procedure for collision sport [40]. It remains to be seen whether this is the most effective way to measure neck strength.

Similarly, neck ROM was assessed by a visual estimation method chosen because it is easily reproduced as a preseason screening procedure and because it has been used many times in the literature [62]. However, as shown by Youdas et al. [38], the intra-examiner reliability of visual estimation is poor and therefore this technique may be susceptible to variable and subjective clinical interpretation.

A further limitation in this study is the higher intrinsic variability in participation found in amateur sport, as opposed to professional sport [49]. Player participation time in this cohort may have varied throughout the seasons, influencing the accuracy of the exposure time calculation method of this study. Moreover, the non-response of some variables, namely perceived stage of career and previous neck injury at the baseline assessment was not reported by injured participants by up to 30% and this may have influenced the results.

Larger studies which consider recent advances in methods and measuring techniques [63] are required. In addition, future studies should evaluate other populations such as youth, professional and women RU, to confirm whether pain detected during preseason ROM assessment is a risk factor for subsequent neck injury in RU in these populations .

Fuller et al, in referencing the short and medium term medical and financial consequences of injury for RU players and their clubs, has suggested that prevention of injury rather than treatment is normally the preferred option [64-65]. Pre-season screening of pain during neck ROM assessment has been shown in this study to be a significant risk factor for neck injury [62], and yet 71% of the community-based RU clubs from the same region as this study do not have any pre-participation screening policy [66]. Fuller et al. [65] found that pre-season neck ROM assessments were only conducted in 44% and 73% of premiership and division RU clubs respectively. Moreover, the use of an examination routine post-injury appears to be uncommon in RU [65]. These reports suggest there is room for improvement [67] in RU at the community level in order to prevent neck injuries through the judicious use of pre-assessment screening.

Conclusion

This study identified a strong association between the detection of pain through pre-season ROM assessment and the incidence of neck injury during play in an amateur men's RU cohort. This suggests the need for pre-participation evaluation to identify this risk factor and the need for strategies to manage the cause of the pain and thus mitigate its possible sequelae. The uptake of policies and practices that screen for the risk factors identified in this study may reduce the impact of neck injury in amateur RU.

Competing interests

No funding was received in the preparation of this manuscript. The authors have no conflict of interest directly related to the content of the manuscript.

Author's contributions

MSS conceived the study, participated in the study design, collected baseline data, trained data collectors, collected data during the games and training sessions at Lindfield RU, drafted and edited the manuscript.

HPP conceived the study, participated in the study design, helped to draft and edit the manuscript.

RB conceived the study, participated in the study design, helped to draft and edit the manuscript.

SW helped to draft and edit the manuscript.

All authors read and approved the manuscript.

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Appendix H. Supplementary data

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CHAPTER FIVE

DISCUSSION

In part Chapter Five was presented on podium as:

The epidemiology of neck injuries in non-elite Rugby Union: a prospective cohort study. **Swain MS**, Pollard HP, Bonello R. Chiropractic and Osteopathic College of Australasia's 8th Biennial Conference. Sydney, Australia - 20-22 November 2009.

Statement of authorship contribution of the MPhil candidate

In our role as co-authors of the podium presentation: 'The epidemiology of neck injuries in non-elite Rugby Union: a prospective cohort study. Swain MS, Pollard HP, Bonello R. Chiropractic and Osteopathic College of Australasia's 8th Biennial Conference. Sydney, Australia - 20-22 November 2009'.

We confirm that Michael Steven Swain has made the following contributions:

- Concept and design of the presentation: MSS 80%, HPP 10%, RB 10%
- Retrieval and preparation of the content: MSS 90%, HPP 5%, RB 5%
- Critical review: MSS 60%, HPP 20%, RB 20%
- Presentation: MSS 100%

Michael S. Swain________________________ Date: ____________

Henry P. Pollard________________________ Date: ____________

Rod Bonello________________________ Date: ____________

Methodological considerations

Sports injury definition

The definition of sports injury is fundamentally important in injury research, because it will restrict the boundaries of the study. Additionally, the comparability of outcome measures between different study groups is based upon the definition of injury. Early studies on the incidence of sports injury were not based on one coherent definition. Some studies included only those sports injuries which lead to an insurance claim, while other studies only considered those sports injuries which presented to hospital or medical departments[45]. More recent studies have focused more on injuries that have led to time lost from play.

It is this lack of consistency and rigour in defining what a sports injury is that makes interpreting the literature difficult. In 1992, van Mechelen *et al*[45] reflected on the problem of defining what a sports injury should encompass, and found that the limited definitions used by some authors obscured the reality of the situation, in what has been described by Walter *et al*[120] as the “tip-of-the-iceberg” phenomenon. These authors advocate a broad, unambiguous and universally applicable definition to allow for meta-analysis of data. In 2007 Hodgson *et al*[110] as well as Orchard and Hoskins[111] presented contrary standpoints in the sport injury definition debate. On one hand Hodgson *et al*[110] argued for the broadest “all-encompassing” injury definition, suggesting that it offers a true and global depiction of the sport injury problem in a team sport. On the other hand Orchard and Hoskins[111] have argued that a narrow “match time loss only” definition provided, while biased, the most accurate and reliable injury definition for team sports. However, they acknowledge the all encompassing definition approach may be more appropriate for individual team and specific injury studies.

Brooks and Fuller divided sports injury into three broad categories[121]. These are: *medical attention/treatment injury*, which is any injury that requires the assistance of sports medicine personnel with or without time lost from training; *full-inclusive time-loss injury*, which is any injury that results in time lost from competition and/or training; and *semi-inclusive time-loss injury*, which is any injury that results in time lost from competition only. Three prospective studies[90, 95, 122] have only considered *fully-inclusive* (game and training) *time-loss injury* as sports injuries, whilst another four studies[69, 80, 123, 124] included only *semi-inclusive* (game-only) *time-loss injury* in their research. A further five studies[72, 86, 125-127] applied an *all inclusive* (time lost and medical attention) sports injury definition described by Hodgson *et al*[110] in their study of neck injury in Rugby Union (RU).

In 2007 the International Rugby Board (IRB) formed the Rugby Injury Consensus Group (RICG) to establish consensus on injury definition and data collection procedures specific to RU[128]. The definition of injury as reported in the consensus document is:

> *"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."

The definition of sports injury adopted in this dissertation is not the same as the RU consensus statement on injury definitions[128]. The research presented in this thesis began at a time when there was wide variation in the definition of sports injury in the RU literature[30], and the definition adopted has been based on the best available information at that time of conception. This study conforms to the broad 'all-encompassing' definitional position as described by Hodgson *et al*[110] as it includes medical attention as well as match and training time loss. The RU consensus document is more specific in the way it sub-classifies medical attention, match play and training injuries. Moreover the RU consensus document specifically defines recurrent injuries, which were identified if not formally defined in our two-year cohort study. The consensus document defines a recurrent injury as:

"An injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury. A recurrent injury occurring within 2 months of a player's return to full participation is referred to as an 'early recurrence'; one occurring 2 to 12 months after a player's return to full participation as a 'late recurrence'; and one occurring more than 12 months after a player's return to full participation as a 'delayed recurrence'."

Justification for the use of this definition is: (1) to conform to the broader category of *all inclusive* injury (time loss and medical attention definition), i.e. it is the mostly extensively applied definition[72, 86, 125-127], (2) It is easy to compare our results with other research that uses broad categories such as medical attention injuries and time loss injuries, both semi and fully inclusive[121]; (3) It has been advocated by leading sports injury epidemiology commentators and successfully applied in other observational sport injury studies[45], (4) it is all encompassing in nature and thus avoids the tip of the ice berg phenomenon in data collection.

Incidence

Incidence is perhaps the most basic measure of risk, and is defined as the development of a new condition in a specified period of time (typically over a playing season). Historically, in the literature the reporting of new injuries has been defined as either the absolute number of new injuries in a given time, or the proportion (e.g. percent) of new injuries in a given time. However, for the sake of comparability, the most meaningful method of reporting incidence is as a rate. Injury rate is calculated by dividing the number of new injuries in a given time by the period that the athlete is exposured to the sport[45, 56, 57, 129].

Prior to the year 2000, the reporting of neck injury in RU did not adjust incidence rates for exposure[30]. Recently several commentators have expressed concern over this method of incidence reporting[3, 57, 121, 129] citing a lack of meaningful interpretation of incidence risk. Brooks and Fuller[121] express concern over the inability to quantify relationships between risk factors and injuries in the sample population with this method. The two-year prospective cohort study in this thesis reports the incidence of neck injury as a factor of exposure time (injury rate). Descriptive statistics of counts and proportions that appear in the literature were included for comparability only in a historical context.

The definition of sports injury adopted directly impacts on the denominator used in reporting exposure time i.e. as a factor of player hours, athletic exposures or matches. There is variation in the literature[30] from total athlete appearances (3 studies), number of games played (2 studies), and athlete exposure time (18 studies). Furthermore, 10 studies included in the systematic review of this thesis failed to report total injury exposure. The choice of the denominator affects the numerical value of the derived data and also its interpretation[129].

Increasingly, studies have adopted the practice of reporting sports injury incidence per 1000 exposure variables which can include athletic encounters or time. This is true for nine of the 33 studies on neck injury in RU[35, 36, 90, 122, 124, 130-133]. Commentators[45, 129] suggest further refinement of the calculation of incidence rate to measure the actual exposure time at risk. This can be achieved by calculating the player exposure per risk hours. Hodgson[129] states that risk hours should ideally include training time as well as competitive participation. This has only been applied in recent times to neck injury in RU in six of the reviewed studies[35, 90, 122, 130-132]. Several authors have recently justified the utility of reporting match and training injury incidence risk separately to allow direct comparisons between studies[3, 57, 110, 121]. The two-year prospective cohort study in this thesis conforms to this by separating match and training injury rates and reporting each per 1000 player hours.

Severity

Incidence data provides only half the epidemiological picture regarding the extent of any sports injury problem[121]. The consequence of sports injury is the severity of the outcome[3].

van Mechelen[13] describes six methods by which the severity of a sports injury may be recorded. These include: the nature of the sports injury, the duration and nature of treatment, sports time lost, working time lost, permanent damage and the cost of the sports injury. The nature of the sports injury is defined by its medical diagnosis i.e. the type, extent and specific anatomical structure/s involved in the lesion. Duration and nature of treatment describes the role of health care professionals in the management of the sports injury, and implies health care costs, loss of time from the sport and work and the impact of these outcomes. Sports injury infrequently results in permanent damage, and this needs to be factored in with the severity of the injury.

There is inconsistent inclusion of severity data as an outcome measure for sports injury risk in athletic populations[30]. This is most certainly the case in the literature on neck injury in RU. When it is included, the most common definition employed is as a factor of the length of time lost from participation[60, 134]. However, the variability in defining severity affects meta-analysis of data. For example, sports injury studies tend to arbitrarily group the severity of injury as slight, minor, moderate or severe, without proper definition of what these categories mean.

In the RU consensus document injury severity was defined as:

> *"The number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection."*

Further, It was recommended that injuries be grouped as slight (0-1 days), minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (>28 days). The two-year prospective cohort study in this thesis defined severity as time lost from participating in sport, with injury type evaluated as secondary measures, and injuries are similarly grouped. However, to the best of my knowledge the Injury Report Form for Rugby Union (IRFRU) recommended in the consensus document has yet to be evaluated for validity or reliability. However, the process of attempting to create consensus is a substantial milestone in ensuring future comparability of RU studies.

Data retrieval

Historically, prospective studies which evaluated neck injury in RU captured little by way of baseline data, and self reported questionnaires with anthropometric or physical assessment procedures were the most frequently applied method of preseason data capture[26, 27, 56, 135, 136]. Problems associated with self reported questionaries have been extensively reported in the psychological literature[137, 138] and now recently also in sports medicine[139]. Similarly, baseline data is important when studying proposed risk. It is the method by which baseline data is captured which governs the validity and reliability of subsequent results[26, 27, 56, 135, 136].

In-season data collection methods directly impact on the validity and reliability of the incidence, severity and risk factor data. Methods used in the literature vary from: weekly telephone interviews[72], a monthly log[86], weekly injury clinics by a team doctor/physician or physiotherapist[35, 124, 140], survey/questionnaires after injury[141-143], accident and emergency presentations[144-146], and a whole weekend log[69]. In the two-year prospective cohort study of this thesis, the Rugby Union Injury Report Form (RUIRF) was used for the collection of neck injury data. The RUIRF was first published in 2000 by McMannus[60], and it is the only validated data collection instrument in RU [147].

Not only are there variable methods of collecting this data but there are potential problems with the way in which risk factors or sub-populations are incorporated into the details of the sports injury, the length of time allowed to pass between injury onset and injury recording, and the credentials of the data collectors.

Several prospective RU neck injury studies[35, 72, 86, 90, 124, 131, 140, 148] have recorded injury particulars at a weekly interval or greater. The greater the time between injury onset and injury recording, the greater the reporting inaccuracy through recall bias. Sport injury is high speed in nature and this makes recall bias an ever present problem which is only compounded by time. In this study data is captured immediately following an injury event and the athlete is followed until deemed fit to return to play. This was achieved by having data collectors present at all games and trainings. This has been applied successfully before in RU[80, 123, 125, 126, 132, 141-143, 147, 149]. This method strengthens the study validity by reducing the rate of missed injury data.

The incorporation of tertiary qualified data collectors in our cohort study facilitated the ability to accurately classify sports injury. Best and Shier suggest this to be as fundamental as the injury definition[150] and is particularly relevant in studies which define an injury according to the medical attention it receives[35, 90, 123, 131, 140, 144-146]. Injury type in the data collection is standardised via the OSICS (version 8), which has been widely adopted in the RU literature[24]. A tertiary qualified sports medicine expert affiliated with a club will likely have a greater ability to describe an injury event[36] such as overuse injuries.

Exposure risk

Injury risk and pattern vary over the football season, which is why the study period should include the entire season, or several seasons, including both the preseason and the competitive season[151]. Studies on neck injury in RU range from as short as one week for a tournament up to 10 years for accident and emergency record monitoring. Typically the study duration is over one or more playing season(s) and this is important as study duration relates to participant exposure time and therefore the accuracy of the estimated injury rate. The duration of our prospective cohort study was 2 years which is typical.

Exposure time is a factor of the number of participants in the population (study size) and the duration of the study. Prospective neck injury data in RU that report athletic injury rate as a factor of exposure time (in hours of play) ranged from: (1) 327 hours of match play form elite men[127] to 16 782 hours of match play for elite men[35] (median 2057 hours); (2) 4 900 hours of training play for elite men[131] to 196 409 hours of training play for elite men[130] (median 17 046 hours) and; (3) 4 958 hours of combined match and training play for elite women[86] to 39 866 hours of combined match and training play for a study population of school-age boys[88] (median 7310 hours). Comparatively exposure time for the prospective cohort study of Chapter four registered 12 860 hours of match time and 18 280 hours of training totalling 31 140 hours of play. With important consideration given to the governing factors of exposure time, study duration as well as sample size, it may be said that this population of RU players were subjected to a similar exposure of RU throughout the playing seasons as in other study populations of rugby athletes therefore has similar levels of incidence estimate.

Sample size and power

This prospective cohort fell short of the calculated study size required for the desired power to reach meaningful associations for some of the selected variables. The sample size calculation used in this method was based on the assumption that risk factors were to be evaluated in groups of exposed and unexposed participants. However, for some variables multiple groups were examined which resulted in lowering the actual power of the study to detect the effect of variables. Schlesselman[51] says that the sample size requirements for cohort studies depends on the incidence and relative risk of the disease or injury. The incidence depends on the exposure factor/s and the occurrence of the disease or injury count. The combined injury count of many of the variables examined in the results section was higher than the 20-50 injury counts described by Bahr and Holme[48] to demonstrate moderate to strong association. However, the categorisation of some variables resulted in small injury counts in some categories which limited the ability to show associations with confidence.

Study size is defined here as the number of participants potentially at risk in sports injury surveillance studies. Study size has varied greatly in prospective cohort studies of neck injury in RU. The sample sizes have ranged from 25 participants which accounted for one New Zealand super 12 rugby squad[127] to 38 933 participants which accounted for the athletes from 7 provincial RU regions of Argentina[69]. Of particular note were six studies[94, 126, 141, 144, 146, 152] which failed to report the number of participants in the study. The median study size in these included studies is 339 participants. The population size of the prospective cohort study of this dissertation was 262 participants which accounted for 8 teams of rugby athletes from two

Australian amateur RU clubs. The study population from this thesis' cohort study lies close to the median sample size of other prospective studies which report neck injuries in the literature.

In prospective studies of neck injury in RU in the literature, incidence ranges from 1 to 96 injury cases[36, 153], with a median value of 10 new cases. In our prospective cohort study, 90 new injury cases were recorded during the study period, which is high and has allowed for greater analysis of variables than all but one previous study.

Reporting

The reporting of prospective neck injury studies in RU is moderate to good. The PRISMA (Preferred Reporting of Items for Systematic Reviews and Meta-Analysis) was adhered to in the reporting of the systematic review of this thesis[154] (Appendix I). Quality assurance in the dissemination of results remains a key issue for comparability of reported information. Recent advances in the dissemination of information have come via guideline documents such as the STROBE Statement[155], which was followed in this thesis to ensure the quality of reporting the results.

Thesis limitations

There are several limitations which have been acknowledged in our two-year prospective cohort study. They are:

(1) Position of play sometimes varied throughout the season, which limits the accuracy of reporting incidence by position of play. This is common in amateur sports as players have a tendency to be 'jacks of all trades and masters of none'. It does however pose a problem for epidemiologists who follow amateur sport who attempt to associate injury risk with player position.

(2) Player participation time in this cohort may have varied throughout the seasons, influencing the accuracy of exposure time. The method of estimating exposure time from the numbers of players in squads with typical training and match duration is less accurate than individual exposure logs. This may have influenced the accuracy of the analysis between incidence and variables.

(3) Non-response of some variables at baseline may have been as high as 30%. This is seen for the variables previous neck injury and perceived stage of career where there are 28/90 unknown variable injury counts. This may have influenced the results of some variables.

(4) It is widely acknowledged that the ‘athlete interview’ method of assessing the mechanism of a neck injury may lack accuracy as it relies on the accuracy of the player’s recall of the incident which occurred at high speed and may have caused some disorientation, and the recall may become even less reliable as time passes[156]. Video analysis, laboratory motion analysis and biomechanical studies may overcome these issues. However these analyses pose their own limitations, such as inability to recreate match situations[156]. This study conducted the ‘athlete interview’ immediately following the injury event in order to minimise the impact of recall bias.

(5) It is widely acknowledged that the ability of a clinician to diagnose the extent of a tissue injury through subjective examination is limited[116-118, 151]. More objective criteria of assessing tissue in lesion include imaging modalities such as ultrasound and magnetic resonance imaging. They were prohibitively expensive and impractical in this study.

(6) The use of a non-validated self-reported questionnaire in identifying variables is a limitation of this thesis. The limitations of self reported questionnaires in

epidemiology have been reported elsewhere by Byun *et al*[157] as well as Sallis and Saelens[158].

(7) The injury counts obtained for some variables, such as illegal play was too low to be evaluated. Bahr and Holmes suggest 20-50 injury counts are required to make moderate to strong associations[48]. Statistically speaking small numbers of injuries upon which the data was collected in this study precludes the examination of many factors of interest to a moderate or higher level of confidence. Given this, cross tabulation of some risk factors is greater than is warranted and apparent given the numbers of injuries in each category. Larger scale studies that collect greater numbers of injury counts among amateur players is required when evaluating risk factors for neck injury.

(8) The evaluation of neck injury and time of season was analysed by collapsing time of season into categories of first third (April – May); the second third (June – July); and the last third (August – September) of the season. Two scheduled rounds are played in eight weeks of August and September leading up to the finals. Only teams that qualify by victory in the scheduled rounds participate in the finals. The vast majority of the cohort failed to qualify for the final rounds in the observation period which accounts for the very low injury counts observed in this study. Future studies that evaluate injury counts over a playing season(s) should differentiate scheduled season rounds from the final rounds in there description of seasonal injury trends.

(9) Neck ROM was assessed by a visual estimation method chosen because it was easily reproduced as a preseason screening procedure and because it has been used many times in the literature[159]. However, as shown by Youdas *et al*[99], the

intra-examiner reliability of visual estimation is poor and therefore this technique may be susceptible to variable and subjective clinical interpretation.

Neck injury in Australian men's amateur Rugby Union

Incidence and severity

Studies on neck injury in RU have been done in the United Kingdom (n=11)[35, 88, 90, 94, 122, 124, 125, 141, 145, 152, 160], New Zealand (n=8)[72, 127, 133, 140, 142-144, 148], Australia (n=4)[36, 63, 123, 126], Canada (n=2)[86, 146], South Africa (n=2)[62, 95], Argentina (n=1)[69] and the United States of America (n=1)[132]. Furthermore, four studies[80, 130, 149, 153] were conducted which gathered data from Rugby World Cup (RWC) tournament play events. The United Kingdom and New Zealand are the most active reviewers of research into neck injury. Four Australian prospective cohort studies[36, 123, 126, 147] that studied the incidence and severity of neck injury in RU were undertaken in the period from 1992-2003 and studied representative populations in first grade men[126], elite juniors[147], professional men[123] and young male populations[36]. To the best of our knowledge, the cohort study of this thesis is the first prospective RU neck injury study to be undertaken on an Australian population of amateur men. This is significant given the under-reporting of injuries pertaining specifically to the neck in amateur RU populations[30] and is timely data, given the changing nature of the amateur game since the 1995 inception of the professional RU era[124].

This study showed that the probability of sustaining a neck injury in Australian men's amateur RU during 2006 and 2007 was:

1) 38.50 match injuries /season (95% CIs: 30.50, 48.00)
2) 6.50 training injuries /season (95% CIs: 3.50, 11.00)
3) 5.99 injuries /1000 match player-hours (95% CIs: 4.77, 7.52)
4) 0.71 injuries /1000 training player-hours (95% CIs: 0.41, 1.24)

5) 2.90 injuries /1000 combined match and training player-hours (95% CIs: 2.30, 3.60)
6) 0.26 repeat injuries /1000 player-hours (95% CIs: 0.13, 0.52)

Representing injury rate as a factor of injuries per season may be of use to those who manage sports injury, giving them an estimate of injury count and better preparing them for a season of neck injury in RU. Neck injury accounts for between 2.1% and 14.3% of all the injuries which occur in RU[30]. The most recent estimate of all-body-region injury rates in amateur (Croatian) men's RU is: 28.22 injuries /1000 match-hours and 1.24 injuries /1000 training-hours[161]. There is little data in the literature on neck injury rates in all types of football. Marshall *et al*[133] compared the incidence of neck injury between North American Football and RU. They found a much lower incidence of neck injury amongst North American Footballers, 2.08 /1000 player-games (95%CI: 1.60-2.55) versus, 8.03 /1000 player-games (95%CI: 4.38-11.67) in RU. The lack of protective sports equipment in RU was considered to account for much of this difference. The relatively high occurrence neck injury identified in this study suggests that neck injury poses a frequent problem to RU players.

Our two-year prospective study showed the consequence of sustaining a neck injury in an Australian men's amateur RU during 2006 and 2007 was:

(1) Minor (< 1 week lost): n=61, 69.3%, 1.96 (95% CIs: 1.50, 2.53) /1000 player-hours

(2) Mild (1-2 weeks lost): n=15, 17.0%, 0.48 (95% CIs: 0.27, 0.79) /1000 player-hours

(3) Moderate (2-3 weeks lost): n=6, 6.8%, 0.19 (95% CIs: 0.07, 0.42 /1000 player-hours

(4) Severe (> 3 weeks lost): n=6, 6.8%, 0.19 (95% CIs: 0.07, 0.42 /1000 player-hours

Minor neck injuries, defined as no additional weeks lost from play, were the most frequent consequence of neck injury, and this result is consistent with findings in published data on professional men's RU[35, 90, 122, 130]. The most recent RU neck injury data found that the median time lost from play due to neck injury was less than one week (5 days) and the average time lost were less than 2 weeks (13 days)[35]. Our research showed on average no more than one week (7 days) lost from play. Moreover, when total time lost was taken into account and averaged out over the season, neck injury led to the injured players missing less than 2 weeks of play.

This study concurs with the reports of others[24, 73] that catastrophic neck injuries in RU are extremely rare as no catastrophic neck injuries were identified during the two seasons of observation.

The probability and consequence of neck injury in this study should be evaluated in the context of a risk matrix. The evaluation of neck injury risk should take into account the balance between costs and benefits to all RU stakeholders. An ideal balance of costs versus benefits needs to be identified while risk is reduced to a level that is "as low as reasonably possible"[162]. Fuller and Ward[162] have identified a suitable semi-quantified risk matrix appropriate for the evaluation of sports injury risk in RU (Figure 5.1). In this risk matrix, the frequency of injury on the x-axis is placed on a subjective five point scale from very unlikely to very likely. The results of our study place amateur RU in our cohort as a likely event on this scale. The harm sustained is described on a six point scale from trivial to severe on the y-axis, with: (1) trivial = no time lost; (2) minor = 1-7 days lost; (3) moderate = 1-4 weeks lost; major = 1-6 months lost; severe = >6 months lost. Our results, as measured by the average time lost from play would place the cohort of amateur RU players at moderate. Accordingly, the risk described by the matrix is tolerable, but there is certainly room for improvement.

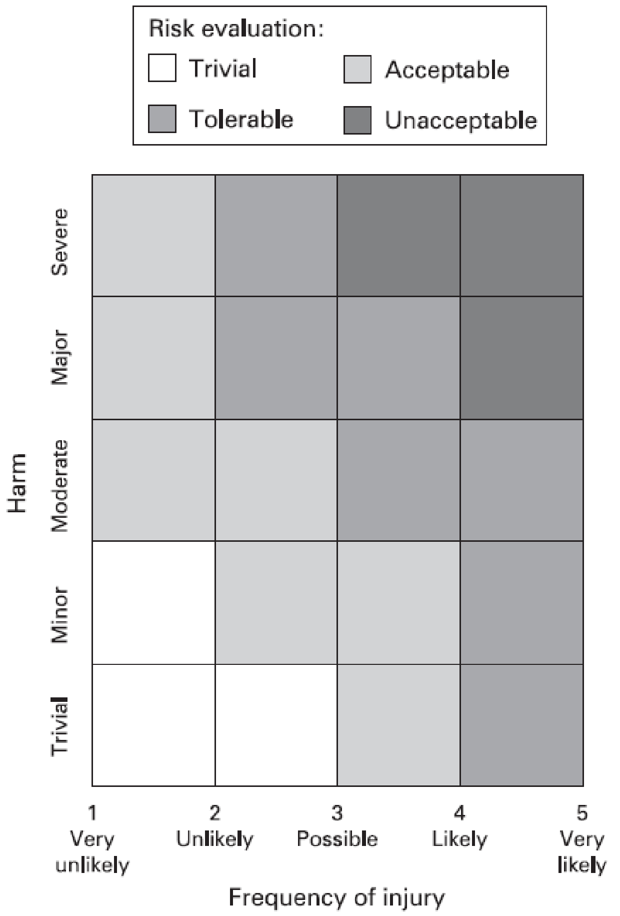

Figure 5.1. Fuller CW, Ward CJ. **An empirical approach for defining acceptable levels of risk: a case study in team sports**. *Inj Prev*. 2008;**14**:256-61. Figure 1, Risk matrix for assessing acceptable level of acute and chronic injuries; p. 257

In the context of the dynamic multifactorial aetiology model of sports injury[48, 163] the following discussion will reflect on the proposed risk factors for neck injury in RU and highlight the contribution this study makes to the literature.

Intrinsic risk

Amateur men's RU

Three studies of amateur men's RU[124, 126, 132] give the incidence of neck injury based on the definitions described by Brooks and Fuller[121] (Table 5.1). The incidence of neck injury in our study of Australian amateur RU players was higher than those reported by these studies, which may suggest that: (a) there is a growing trend of neck injury in amateur men's RU, and/or (b) this study population is exposed to a different profile of risk factors and inciting events that results in their higher incidence of neck injury, or (c) neither (a) and (b) are true. One unique feature of this study compared to prospective studies of the past is its specificity to observe only neck injuries. The possibility remains that we find what we're looking for and that the motivation of data collectors to report neck injuries in a more diligent manner was heightened. There is a requirement for further large studies that evaluate the incidence of neck injury in amateur men's RU. Preferably this should be undertaken in conjunction with an all injury observation approach to minimise observational bias.

Table 5.1
Neck injury incidence in amateur men's RU

Definition	Study	Match	Training	Combined
Semi -Inclusive	Garraway, W[124] 1997-1998	1.07 (CI: 0.64, 1.49) /1000 playing hours		
All Inclusive	Hughes, D[126] 1992			0.64 (CI:0.26, 1.33) /1000 player hours
	Kerr, H[132] 2005-2006	0.43 /1000 player hours	0.41/ 1000 player hours	
	Swain, M[164] 2006 - 2007	**5.99 (CI: 4.77, 7.52) /1000 player hours**	**0.71 (CI: 0.41, 1.24) /1000 player hours**	**2.9 (CI: 2.3, 3.6) /1000 player hours**

Professional versus amateur men

In RU the incidence of sports injury has been shown to rise with the level of professionalism[24]. With respect to neck injury, the level of play has been proposed as a risk factor for spinal cord injury[73]. Reports that associate level of play with neck injury suggest: (1) the higher the player's skill (as seen with level of play) the greater the protective effect[78], and the conversely; (2) the higher the competition level, the more aggressive and dangerous the style of play[165], and (3) danger is associated with mismatching players of different size and strength[91, 166] as well as experience[75]. One study[124] compared the neck injury rate between professional and amateur men, and concluded that there was no significant difference. More research is needed to substantiate or refute these findings.

The incidence of neck injury during a RU match in our study falls within the incidence range of professional RU populations reported in the literature, which contradicts the perception that neck injury risk is higher at professional levels (Table 5.2). But the incidence of neck injury that occurred during training in our cohort of amateur RU players is higher than that reported in professional populations[35, 130]. The training exposure time of professional athletes on average exceeds that of the amateur populations[30, 35, 130, 164], so the higher rate of injury during this time in amateur players may be due to training activities in amateur RU that pose a higher risk for neck injury, a highly speculative proposition that requires further research.

Table 5.2
Neck injury incidence of professional RU versus this study

Definition	Study & year/s	Match injury rate	Training injury rate
Time-loss semi-inclusive	Bathgate, A[123] 1994-2000	2.75 (CI: 0.89, 6.41) /1000 player hours	
	Jakeot, I[80] 1995 RWC	2.28 (CI: 0.74, 5.32) /1000 player hours	
Time-loss fully-inclusive	Fuller, C[35] 2003 & 2004	6.46 (CI: 5.31, 7.86) /1000 player hours	0.06 (CI: 0.03, 0.11) /1000 player hours
	Fuller, C[130] 2007 RWC	4.2 (CI: 2.1, 8.3) /1000 player hours	0.1 (CI: 0.0,0.4) /1000 player hours
All inclusive – time loss/medical attention	Holtzhausen, L[131] 1999	1.4 /1000 player hours	
	Targett, S[127] 1997	9.17 (CI: 1.89, 26.81) /1000 player hours	
	Swain, M[164] 2006-2007	**5.99 (CI: 4.77, 7.52) /1000 player hours**	**0.71 (CI: 0.41, 1.24) /1000 player hours**

Amateur men versus women

One author has suggested that their findings of an increased incidence of neck injury in female athletes is due to inadequate upper body strength and inexperience with collision sports[167]. However, there is conflicting opinion as to whether playing sport is riskier for women than it is for men[28, 94, 146, 149, 167] based on incidence outcomes. Systematic review of the literature has shown that the incidence of neck injury in men's and women's RU is similar[30], however there is a paucity of information on this. Similar to amateur RU there is an unfortunate lack of data from cohorts of women RU players in the literature. Keeping in mind the very low neck injury counts captured prospectively in women RU it appears that the amateur men have a considerably higher neck injury incidence (Table 5.3).

Interestingly Schick *et al*[149] found neck/cervical injury to be one of the most commonly injured regions in their women's population, which is not the trend in men's RU[24]. But there is insufficient data to compare neck injury consequence between men and women. Small neck injury numbers in women's RU requires greater research efforts to assess neck injury in women's RU.

Table 5.3
Neck injury incidence for men in this study (Swain, M) versus women

Definition	Study	Gender	Match	Training	Combined
All inclusive – time loss/ medical attention	Carson, J[86] 1997-1998	Female			0.61 /1000 player hours
	Doyle, J[125] 2002	Female			0.26 (CI: 0.03, 0.93) /1000 player hours
	Kerr, H[132] 2005-2006	Female	0.51 /1000 player hours	0.17 /1000 player hours	
	Schick, D[149] 2006	Female			1.36 (CI: 0.59, 2.68) /1000 player hours
	Swain, M[164] 2006-2007	**Male**	**5.99 (CI: 4.77, 7.52) /1000 player hours**	**0.71 (CI: 0.41, 1.24) /1000 player hours**	**2.9 (CI: 2.3, 3.6) /1000 player hours**

Youth versus amateur men

There is conflicting information over the role of the player's age as a risk factor for neck injury in RU[33, 37, 69, 78, 142, 143, 165, 168-170]. But a systematic review of the literature does not demonstrate a discernable difference between the incidences of neck injury as a factor of player age. In 2002-03 McIntosh *et al*[36] performed a two-season prospective cohort study to identify the incidence of head, neck and facial injuries in youth rugby. This study defined injury as semi-inclusive time lost from the game. It reported the incidence of neck injury of junior boys to be 3.3 neck injury /1000 player match hours (95% CIs: 2.7, 4.0). The neck injury rate of 5.99 neck injuries /1000 player match hours (CI: 4.77, 7.52) found in amateur men's rugby is consistent with the trend expressed in non-regional specific studies on RU[56], where the incidence of sports injury rises with player age[24]. Moreover, 21 of the 96 (0.7 /1000 player game hours) neck injuries reported in this study resulted in one week lost from play, which is similar to our results. Neck injury rates appear to increase from between 17 to 23 years of age[56]. This may be due to the increased stature and body mass associated with the senior age range, which when coupled with strength and speed result in a higher injury rate[36, 56].

Age of player

The risk of neck injury in senior players rises due to (1) aging in the lower part of the neck which then becomes prone to damage[171], and (2) delayed recovery and hence increased severity of injury[92]. There are however many factors to consider besides the aging of the skeletal and ligamentous structures such as player experience, size, and power; level of play, fitness, level of aggression, region of play, player mismatch and coaching/practice techniques at the scrum, and these have lead to conflicting opinions[73]. There is a trend in amateur players in our study toward higher neck injury rates up to 29-34 years of age (p=0.07). There was no evidence in our study that player age impacts on the severity of neck injury in senior men. Our study therefore supports the notion that injury rate increases from junior to senior age groups, however injury rate within senior age groups are similar.

Position of play

One of the most widely discussed player related factors for neck injury in RU is the position of play. In the literature the neck injury rate is seen to be higher in players who play in the forward positions when compared to players in the back positions. The front row positions have been specifically indicated as high risk positions[33, 35, 36, 69, 75, 78, 85, 87, 95, 126, 172]. Conversely, prospectively captured severity of neck injury appears to be uniform across player position[35, 164]. The findings of our study concur with the literature where the front row players, followed by the back row players are the most likely positions of play to sustain neck injury. Interestingly the front row players were the only positions to sustain the most severe injuries in this cohort, even though this association was not statistically meaningful (p = 0.36). It has been reported that there is heightened risk of neck injury for players playing out of their usual position, or playing in a new position for the first time[76, 168]. This is thought to pertain primarily to front row players[76, 168, 173]. Previous reports highlighted morphologically unsuited (long slender necks)[174] and technically inexperienced front row players[75, 76, 175] as being at greater risk of neck injury. This risk has been heeded by those who govern the game under law 3.5 from Laws of the game: RU, which requires suitably trained and experienced players in the front row[100]. This association was not evaluated in this study, and to the author's knowledge there is no published literature on this aspect.

Grade of play

A player's level of play has been proposed as a risk factor to spinal cord injury, with the hypothesis that increased skill may have a protective effect[78]. This hypothesis has been offset by suggestions that higher competition has a more aggressive and dangerous style of play[165], and that danger is associated with mismatching players of different size and strength[91, 166] as well as experience[75]. Systematic review of the literature[124] has shown that the incidence rate of neck injuries in professional and amateur senior male RU players, and between increasing grades of play. Our study showed that there was a trend toward lower grade players taking a longer time to return to play following a neck injury (p = 0.10) but this may reflect a reduced commitment that lower grade district/suburban players have towards the game.

Experience - years of play

Player inexperience has been proposed as a risk factor for neck injury in RU, particularly for front row players who are involved in scrummaging[75, 76, 91, 170, 176, 177]. In turn a law change (law 3.5) was introduced which stipulates there must be '*suitably trained and experienced players in the front row*'[100]. All studies to date which propose player experience as a risk factor for neck injury are descriptive and retrospective and do not undertake analytical assessment. This study found no correlation between neck injury incidence (p=0.17) or severity (p=0.43) and a player's experience. It is unlikely that further risk mitigation strategies which targets player experience will result in neck injury reduction with consideration of the dynamic multifactorial model of sports injury aetiology.

Perceived stage of career

Perceived vulnerability through neurotic behaviour or alternatively perceived invulnerability through risky-behaviour has been described by Deroche *et al*[178] as an injury risk factor in RU. They identified that previous experiences with injury were positively related to perceived susceptibility to sport-related injuries. Our study is, to the best of my knowledge, the first to propose and evaluate the perceived stage of a player's career as a risk factor for neck injury in amateur RU. There was a trend (p=0.07) which suggested that players at their perceived playing peak may have a higher risk for neck injury, possibly due to a greater risk taking or a more aggressive style of play. It is yet to be seen if a confounding variable or the relatively low (n=15) injury counts recorded in each peak and post peak groups was responsible for the near significance. Future studies should adopt validated tools in psychological perceptions and be larger than this study to identify the role, if any; perceived stage of career has on neck injury risk.

Ethnic origin

Research on RU players in the Fijian and New Zealand Maori populations has shown a higher incidence of neck injury[74, 179]. Moreover, it has been suggested that there may be regional variations in a population such as weather, field surface conditions and player morphology which could influence factors that contribute to the risk of sports injury[73]. Our study found no association between ethnicity and the risk of neck injury in our cohort of amateur RU players.

White versus blue collar occupation

Occupation has been proposed as a player related risk factor for neck injury in RU[73] but it has not been evaluated to date. Potentially an amateur athlete's occupation can impact upon his ability to tolerate specific work related tasks. Moreover, specific occupations require greater physical effort from the neck region therefore the propensity for neck fatigue may be higher. We divided occupations into the broad groups of white collar and blue collar under the assumption that white collar workers may be predisposed to more sedentary work activity which require the individual to adopt office related postures. Potentially they may be exposed more frequently to office related work stresses (both physical and psychological) which may involve neck micro trauma. Conversely we proposed that blue collar workers perform greater manual labour and may be predisposed to work related neck macro trauma. This study showed no correlation between a player's occupation and neck injury risk in RU.

Alcohol consumption

Heavy alcohol drinking patterns have been reported in RU[136]. This has been reported as a risk factor for sports injury in RU[56], and a potential risk factor specifically for neck injury[73]. This study evaluated the role of alcohol consumption as a risk factor for neck injury. It found no association between alcohol consumption and the risk of neck injury. While heavy drinking patterns may pose other adverse health risks it does not appear to affect the risk of neck injury in Australian men's amateur RU.

Pre-season preparation volume

Player pre-season preparation volume has been proposed as a risk factor for sports injury in RU but not specifically for neck injury[56, 81]. One study conducted on a similar non-elite RU cohort found that higher volumes of weekly physical activity and pre-season training were associated with higher subsequent in-season incidence of match injuries[81]. The authors hypothesized that more training lead to higher levels of confidence and subsequent risky playing behavior, a "need to win" mentality, higher rates of preseason injury which limited players later on, and residual fatigue from preseason training which limited a player's peripheral vision. Our study is, to the best of my knowledge, the first to propose and evaluate this risk factor specifically for neck injury. Whilst we found no association between pre-season training hours and the incidence of neck injury, we did find that the severity of neck injury was weakly related to hours of preparation (p = 0.07) with increased preparation time being associated with a prolonged period lost from play. This study had low injury counts in the higher severity groupings therefore larger studies in the future are required to evaluate pre-season preparation volume as a neck injury risk factor.

Type of pre-season preparation

Player pre-season preparation volume has been proposed as a risk factor for sports injury in RU but not specifically for neck injury[180]. To date the type of pre-season training has been divided into endurance and strength training[122, 180]. Our study compared those players who did weights training (resistance) with those that did not, and found no association between resistance training and neck injury risk.

Previous and current neck injury

Previous injury experience has been identified as a risk factor for in-season injury[56], but not specifically for neck injury. Moreover, Lee *et al*[181] found an increased risk of rugby injury for professional players who were injured or were carrying an injury at the end of the previous season. These findings emphasize the importance of full rehabilitation from injury before athletes return to play[56]. In this cohort players who recalled previous RU neck injury fell just short (p=0.06) of a significant association between previous neck injury and the incidence of more neck injury subsequently incurred. Adequate injury counts were obtained for previous neck injury which raises the suspicion of a confounding or hidden variable which was not identified in this study.

Pain with motion

Pre-participation screening has long been endorsed in amateur RU, but there has not been any evidence supporting its importance until now[41, 182-185]. Our study is the first, to the best of my knowledge, which evaluates pain on preseason active ROM assessment as a risk factor for neck injury in amateur RU, and found it to be a significant risk factor (p=0.002). Injury counts in the exposed and unexposed groups were within the 20-50 injury counts suggested by Bahr and Homles[48] to detect moderate to strong association. Fuller *et al*[184], in referring to the short and medium term medical and financial consequences of injury for RU players and their clubs, suggest that prevention of injury rather than treatment is normally the preferred option[186]. Pain with neck motion can be identified during pre-participation screening[159]. It has been reported that 71% of community based RU clubs from the same region as this study cohort do not have a pre-participation screening policy[183]. Fuller *et al*[184], found pre-season neck ROM assessments in premiership and division RU clubs were only conducted in 44% and 73% of the clubs evaluated. Moreover, the use of a pre-participation examination routine post injury appears to be uncommon in RU[184]. These reports and our results indicate a great need for improvement[187, 188] in pre-participation screening in RU, particularly at the community level. Potentially improving a player’s status from pain on pre-season neck movement to no-pain on pre-season neck movement may provide an effective risk mitigation strategy. This study’s finding that neck pain on preseason assessment is an aetiological factor for neck injury in RU is an important second step in the sequence of prevention. Further study is required to evaluate the efficacy, efficiency and compliance of pre-season screening measures in the prevention of neck injury in RU.

Motion Restriction

Gemmell and Dunford[38] have previously measured cervical spine ROM in amateur RU players via the use of an inclinometer device. They found decreased cervical range in motion for all of the backs and forwards. With a similar device Lark and McCarthy[189] showed a reduction in cervical ROM which was significantly greater than age matched non-RU players. A second study by Lark and McCarthy[189] found this functional deficit can be produced by a single game of RU. Our study found no association between reduced cervical mobility (found in 56% of players) and the incidence of neck injury

Neck Strength

Several reports[93, 94, 96, 126, 182, 190-194] have suggested, but not shown any evidence that inadequate neck strength poses a risk to neck injury in RU. It may appear intuitive that neck strength and the application of strengthening exercises may function to prevent the onset of neck injury in rugby though physical preparation. This is thought to occur via specific adaptation to imposed demand (SAID)[191, 193, 195, 196]. Our study could not evaluate this as a possible risk factor, as only two cases of reduced neck strength was found in this cohort. It is also unclear how best to test for neck strength, and the methods proposed by Oliver and Toit[182] may prove to be a better predictor of neck injury in a RU population.

Cervical stability (deep neck flexor endurance) test

Beazell[197] has reported the loss of neuromuscular control by the deep neck flexors following neck injury in a front row forward player. Our study did not find an association between cervical stability and increased neck injury in Australian amateur men's RU.

Extrinsic Risks

Time of season

A review by Quarrie *et al*[73] identified the proportion of early season cervical spine injuries in RU to be high. They suggest this observation may be associated with lack of pre-season conditioning, lack of experience and skill, position mismatches, lack of continued practice, lack of impact conditioning and hard grounds (southern hemisphere). Fuller *et al*[35] recently compared early, mid and late season injuries to the cervical region and found a slow but significant increasing trend as the season progressed. Our study did not show an association between the time of season and increased rates of neck injury. Further, the low exposure of players in our study to RU in the final third of the season corresponding with the final playoffs, limited this study's ability to make inference about injury trends in the later part of the season.

Period of game

This study corroborates the findings of others that neck injury occurs more frequently in the second half of match play[35]. One study implicates player fatigue as the possible cause[35] of neck injury. Bathgate *et al*[123] suggest that player substitution rules may be one way to modify the injury rate identified in the second half[123]. Only recently in 2010 has NSW suburban RU introduced a new player substitution law (Law 18) which allows a maximum of eight substitution per team per match[198]. Potentially this measure could reduce the neck injury incidence in this RU cohort. Ideally in the event of player fatigue, coaches should consider implementing this replacement policy at the high risk neck injury positions of play such as the front row and back row players.

Inciting events

Match versus training

Match play is the most obvious risk factor associated with the incidence of neck injury[72, 75, 78, 85, 87, 96]. Our study corroborates these findings ($p < 0.001$). However, our study and the literature show that the severity of injuries appear to be similar for both match play and training[35, 90, 122, 130, 132]. Potentially, the game related risk factors that Meeuwisse[163] categorises as enabling factors are of greater significance for increasing the risk of neck injury than training related factors. Enabling factors are thought to be the result of the game intensity and associated fatigue from increased ball in play time and exposure to contact events[122]. Moreover, there has been a recent shift away from contact and skills related drills in training activity which may reduce the risk during training[24, 122].

Phase of play

The tackle, scrum and ruck/maul have drawn the greatest attention as risk factors for neck injury. Although injury incidence has been investigated prospectively[35, 36, 88] and retrospectively[33, 85, 87, 91, 152, 153, 168, 170, 173, 199, 200], there is a distinct lack of data on the risk for severe neck injury in these phases of play. However, the majority of the catastrophic neck injuries reported have occurred in the scrum or the tackle phases of play. Our study showed no increase in the risk of neck injury in these phases of play ($p=0.42$) even though only neck injury resulting in not less than three weeks' time loss from play occurred during scrums and tackles.

Figure 5.2. Sean Walsh, Scrum phase of play - IMG_4288.JPG [Online] http://www.lindfieldrugbyclub.com/gallery/, May 19 2011. Reproduced with permission

Quarrie *et al* in their 2002 neck injury review report the scrum (Figure 5.2) to be the most frequent cause of cervical spine and spinal cord injury[73]. Subsequently there have been calls to reduce the number of scrum-like plays or change the organisation of the scrum[199]. In their cohort study injuries occurred most frequently in the tackle followed by the scrum[24, 124], a result also seen in our study.

The tackle phase of play is now the major overall cause of neck injury[35, 36, 200]. It is still unclear whether this is a result of change in exposure to different phases of play[200] or players playing outside their usual position[35]. The back row forwards[35] and various positions in the backline[87] have been reported to have a propensity for tackle related neck injury in professional men. The contact phases of play which include tackling or being tackled have a high propensity for injury[114, 201]. It appears that the changing style of play has seen an increase in the tackle component of play (such as a faster game) which may account for the proportional shift of neck injury away from scrum play and towards tackle phases.

Fuller *et al*[35] prospectively found cervical nerve root injury to be the most common type of tackle neck injury. Previous reports have highlighted potentially dangerous tackle techniques which include high tackles (Figure 5.3), spear tackles, and double tackles. Subsequently rule modifications have been introduced to limit high tackles and spear tackles[67, 202, 203].

Figure 5.3. Sean Walsh, High Tackle - IMG_4257.JPG [Online] http://www.lindfieldrugbyclub.com/gallery/, May 19 2011. Reproduced with permission

Reports on scrum related neck injury highlight the predisposition of the front row[33, 35, 36, 126, 131, 168, 172], in particular the hooker[76, 78, 85, 87, 168, 173], to sustain scrum related neck injury. This was also seen in our study. Neck injury during scrummaging is thought to occur more frequently from scrum engagement and collapse (Figure 5.4) as opposed to “popping” the engaging front row player[73]. A recent prospective study on spine injuries in professional men's RU found facet joint injuries were the most frequent scrummaging neck injury[35]. This was not the case in our study with transient cervical neuropraxia occurring at a similar rate to facet joint injury. Several authors have commented on a decreased incidence of neck injuries in the scrum due to law changes[87, 91, 145, 170, 173, 204-206]. Recent studies from New Zealand[200, 204] and France[168] suggest there may have been a decrease in scrum related neck injury, however it is unclear whether this trend applies to other regions.

Figure 5.4. Sean Walsh, Scrum collapse - IMG_4060.JPG [Online] http://www.lindfieldrugbyclub.com/gallery/, May 19 2011. Reproduced with permission

The ruck/maul (loose play) (Figure 5.5) phase of RU does not appear to have as high a frequency of neck injury as the scrum, or tackle phases of the game[35, 73]. Forwards have previously been reported to have a higher inclination to ruck/maul related neck injury[170, 207]. In our study ruck and maul neck injuries occurred only slightly less frequently than neck injuries in the scrum and tackle phases of play. Silver[91] described a dramatic increase (from nil) in ruck/maul cervical (cord) injuries that occurred in the 1970s with the advent of new tackle laws, which lead to dangerous practices such as 'heeling' the grounded player[202, 207]. The most common type of neck injury from ruck/maul appears to be cervical facet joint injury[35]. Since then rule modifications have reduced these practices[100]. During the period of time over which this study was conducted, experimental law variations (ELVs)[159] were introduced, which allow the maul to be collapsed "safely". This may have been one factor which reduced the incidence of neck injuries in the ruck that we reported here.

Figure 5.5. Sean Walsh, Ruck/Maul (loose play) - IMG_4294.JPG [Online] http://www.lindfieldrugbyclub.com/gallery/, May 19 2011. Reproduced with permission

Legal versus illegal play

Early reports from New Zealand[85], England[91], Australia[92], and South Africa[78] identified foul play as a risk factor for spinal injury, however there is a scarcity of data on this in recent times. Strict enforcement of the laws of the game and heavy penalties for deliberately illegal and foul play[173] have reduced the incidence and hence reporting of such neck injuries, and our study did not encounter this type of play.

Mechanism of injury

Case reports in the literature describe uniplanar neck motions that exceed normal physiological ranges which can result in cervical spine and spinal cord injury[37, 165, 208]. Authors have described an association between the phase of play and the mechanism of injury[35, 67]. In our study several directions of neck movement were reported during a single neck injury event, none of which were associated with a particular phase of play. This may be due to the dynamic and unpredictable[114] nature of contact events in RU at the amateur level. There was a mild trend towards compression as the mechanism of neck injury being associated with severity of injury. Of the five mechanisms reported (compression, extension, flexion, rotation, and side bend), compression was the only non-physiological neck motion and has no dynamic supporting structures to absorb this direction of force. Neck compression in contact sports has previously been reported to occur via a blow to the vertex of the head resulting in spinal cord injury. A player’s spatial awareness and extent of visual fields impact on his ability to identify potential contact events. Increasing player awareness, potentially through coaching methods, directed at these contact phases of play with particular reference to safe head and neck position may be one method of reducing the risk of neck injury[114, 201]. Moreover, teaching players to maintain their field of vision towards opposition players, which may require the neck to be extended (head up, eyes forward), may reduce vertex blows to the head in amateur players.

Injury type

There is limited prospective data on the types of neck injury in RU in the literature[30, 35, 133]. Cervical spine facet mediated injury followed by transient cervical nerve root injury (stingers/burners) are the most frequently diagnosed types of neck injury RU[35, 164]. Marshall *et al*[133] compared American football and RU and found that similar types of neck injury occur which may reflect the similarity in physical demands placed on these athletes in a contact and collision sport. The most frequent types of injuries we observed were cervical sprain/strains and stinger/burner type injuries. Greater understanding of tissue in lesion may allow for more appropriate therapeutic intervention methods to be developed and researched in risk mitigation.

Risk factors not evaluated in this study

There are risk factors which have been reported in the literature which were not evaluated in this prospective cohort study and should be considered as potential factors in the multifactorial model of sports injury aetiology.

Anatomical abnormality (congenital/developmental & acquired)

Several studies[40, 41, 172, 177, 206] have reported on the presence of acquired degenerative joint disease, which in these study front row RU players appears to be premature when compared to age-matched controls[40]. The degenerative process may have started when these athletes were as young as 19 or 21years of age[40, 41]. Such degenerative joint disease is thought to be acquired following the repetitive traumatic forces sustained by players in these positions through scrum related play. As such, the subsequent risk of acute or chronic neck injury[41] lies in the form of neuropathy (typically neuropraxia) secondary to stenosis (typically canal narrowing, however theoretically lateral recess stenosis also). Recently Castinel *et al*[41] identified an elevated risk of spinal injury in athletes with an abnormal medulla-to-canal ratio greater than 0.7 as identified on dynamic MRI assessment. In addition to traumatic acquisition of cervical anomaly, Elias *et al*[209] report on the case of a RU player who acquired an osteoblastoma of the cervical spine. They suggest that pre-existing conditions may predispose the athlete to "stinger/burner" injuries, which should prompt the clinician to search for secondary underlying aetiology in athletes with recurrent burner episodes.

Knowledge of risk factors

Burry and Gowland[85] in 1981 drew attention to the lack of awareness (98% of injured players) injured rugby athletes had to having sustained a cervical injury. Concern has been raised over the coachs' ability to identify potential risk factors and immediately manage neck injury if required[85, 93]. This is especially relevant as it has been stated that: "*It is the responsibility of those who coach or teach the game to ensure that players are prepared in a manner which ensures compliance with the laws of the game and in accordance with safe practices"*[100]. Therefore, as emphasised by Quarrie *et al*[200] educational initiatives such as "RugbySmart" in addition to law modifications alone may provide a more viable option in decreasing risks associated with spinal injury.

Early/Immediate management

Immediate management of serious neck injury is thought to impact on the possibility of subsequent neck injury[87, 93, 165, 166, 170]. While not an incidence risk factor, it is thought that the quality of the initial management by the attending first aider or health care professional can impact on the subsequent severity of the neck injury[87, 165, 166]. The recognition of signs and symptoms and appropriate preparation for transportation to definitive care appears to be of particular importance. Cooney *et al*[93] described that in the absence of qualified healthcare personnel the huge responsibility of immediate management falls frequently on the coach's shoulders. Which raises the question, are requirements to have qualified healthcare personnel at organised RU contests adequately mandated and enforced?

Law changes

The laws of the game provide the framework for which the contest is conducted and to what extent (how and when) contact events, and their propensity to cause injury[35] may occur. Several studies[87, 96, 145, 170, 173, 204-206] have described the manner in which law changes may impact on spinal or cervical injury.

Recommendations

This study has identified a need for further research into key aspects of the neck injury problem in RU as there is room for improvement in reducing the risk of neck injury in men's amateur RU.

Several methodological issues have been identified in this study such as the definition of injury, the methods used to report and collect incidence and severity data and the importance of adherence to the 2007 RU consensus statement[128]. Future prospective RU studies should conform to this consensus document so that meaningful comparison of study data can be made between study populations. This study also highlights the methodological importance of calculating exposure, study size and power and addressing methods of data reporting which are not outlined in the consensus statement. Future reporting of studies should also be guided by documents such as the STROBE statement[155].

Methodologically, prospective cohort studies are generally limited by the large amount of data required in order to allow risk factors of interest to be evaluated with any confidence[56]. This study was limited with small injury counts in the evaluation of some risk factors. Therefore, the author of this dissertation strongly recommends future studies that evaluate risk factors for neck injury in RU observe a minimum 200 injury counts, and that variables and categorises of variables evaluated have no less than 20 injury counts. This is consistent with the report of Bahr and Holmes[48] and their recommendation towards evaluating risk factors with confidence.

Amateur athletes comprise the largest proportion of those who play RU[24]. However, there is an under-reporting of neck injury events at the amateur level of RU. Presumably there is a difference in the way professional/amateur, men/women and youth/seniors play the game. This study suggests that the rate of neck injury in this cohort of amateur men's RU has escalated to be on par with professional men in recent years. The findings of this study need to be confirmed by future studies on amateur populations in order to corroborate this studies recommendation, proposals and conclusions.

In the dynamic multifactoral model of sports injury aetiology there are several facets of neck injury in men's RU which require further evaluation (Table 5.4). Similarly, as described in this Chapter, there are risk factors that are unlikely to prove useful in RU neck injury mitigation and as such have not been recommended for future study.

Potentially, pre-participation screening of athletes is one method of mitigating the outcome of neck injury in RU[184]. In accordance with the third step in the sequence of prevention[45], cervical spine range of motion assessment has been proposed in this dissertation as one preventative strategy, due to the association found between neck pain on cervical ROM and neck injury incidence. However, in the revised sequence of prevention the efficacy, efficiency and compliance of mitigation strategies must first be evaluated for validity and suitability before the real world application of those measures are known[46, 47]. Further study should be directed at the validity and suitability of cervical spine screening protocols based on the findings of this dissertation.

Table 5.4
Recommendations for future study of risk factors for neck injury in RU

Recommended for future study	Not recommended for future study
Player age	Grade of play
Player position	Player experience
Perceived stage of career	Ethnic origin
Pre-season preparation volume	Occupation
Previous neck injury	Alcohol consumption
Anomalies with ROM and strength assessment	Type of pre-season preparation
Match play	Time of season
Phases of play	Illegal play
Time of game	
Mechanisms of injury	

Further study that evaluates the mechanisms of neck injury is required to corroborate the severity association identified in this study. Moreover, studies which evaluate the association of high risk practices during the contact phases of play may inform preventative strategies directed at the phase of play. Possible correlation between mechanism of injury and injury type should be investigated to inform therapeutic intervention studies in risk mitigation.

Prevention strategies

The goal of preventative strategies is to reduce risk to a level that is “as low as is reasonably possible”[162].

Increasing player awareness through educational programs such as RugbySmart has been shown to reduce the rate of scrum related neck injury in New Zealand[200]. Unlike the scrum the direction and size of force in tackles are far less predictable. The safety directives established under the RugbySmart program state correct head position to avoid hitting an opponent head first is an essential component of a safe tackle. These safety directives should be expanded to encourage a head up neck position so that the player’s visual fields account for the opposition player’s field position. The RugbySmart safety directives were available as an internet reference during the study period of this cohort; however neck compression was still reported as the most frequent mechanism of neck injury. Perhaps compliance or behavioural issues limited the efficacy of the RugbySmart program in this cohort. More stringent policy to adequately disseminate and implement the RugbySmart safety directives to district and suburban NSW RU may reduce the risk of neck injury in this cohort of amateur men’s RU.

The newly introduced 2010 player substitution rules provide a positive strategy to combat the effects of player fatigue which may be associated with late match play and player position risk. Further prevention through this strategy may come via specific position interchange which targets those positions that have a high rate of contact and collision such as front row and back row players. This strategy should be monitored by coaching staff, and tailored to the activity tolerance level of the individual athlete.

Pain generated on active neck ROM assessment can be identified pre-season through player screening procedures. Player screening is relatively inexpensive and incurs minimal cost to RU clubs at the amateur level of the game. The uptake of screening procedures that assess active cervical spine ROM and identify players with pain during this assessment is one method of determining players at risk for neck injury.

CHAPTER SIX

CONCLUSION

Principal findings

The broad aim of this thesis was to assess the risk of neck injury in Australian men's amateur Rugby Union (RU). This involved a stepwise approach that first identified the probability and consequence of neck injury, followed by establishing the aetiology, mechanisms and types of neck injury. This body of work contributes to an evidence informed approach to preventing neck injuries in amateur RU.

A systematic review of the literature revealed that the current understanding of risk factors for neck injury in RU is hindered by inconsistencies in the study designs and a lack of scientific rigour applied to identifying either the risk factors or the mechanisms of injury. Reports on the incidence of RU neck injury ranged from 0.26 (CI: 0.08, 0.93) to 9.17 (CI: 1.89, 26.81) /1000 player hours for mixed RU populations in studies that adopted an *all-inclusive* sports injury definition. There is a significant lack of consequence data for neck injury in RU.

In this study of a cohort of Australian men's amateur RU players, the incidence and severity of neck injury was similar to recently published data on professional populations. Several previously described trends were confirmed to exist in this amateur population which included:

- Match play is associated with a higher incidence of neck injury.
- Front row and back row forward positions were at greatest risk of sustaining a neck injury.
- The tackle followed by the scrum were the most likely phases of play to be associated with a neck injury.
- Facet mediated pain was the most frequent type of neck injury recorded.

- Neck injury occurred more frequently in the second half of the game.

This study furthers the understanding of neck injury in men's amateur RU by highlighting risk factors which are unlikely to be associated with neck injury. These factors include:

- The type of pre-season training
- Alcohol consumption
- Occupation
- Ethnic origin

This study makes an original contribution towards a better understanding of neck injury in men's amateur RU. Unique findings derived from this prospective cohort study include:

- Compression mechanisms of neck injury appear to be associated with a greater time lost from play.
- There is a strong association between the incidence of neck injury and pain reported during pre-season ROM assessment.

Practical implications

This thesis provides direction for future study of neck injury in RU. Studies of adequate sample size and power that conform to the RU consensus statement should explore intrinsic factors such as: player age, position, perceived stage of career, pre-season preparation quantity, previous neck injury and anomalies with mobility and strength. Extrinsic factors which should be explored include match play, phases of play, time of game and mechanisms of injury.

Screening of players for neck pain on ROM assessment will highlight at-risk individuals prior to the commencement of the playing season. It is proposed that interventions that result in the restoration of pain free movement may reduce the incidence of neck injury in Australian men's amateur RU

This thesis quantified the incidence and severity of neck injury in RU; in turn it provides a yardstick for future studies that evaluate neck injury in RU.

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APPENDICES

Appendix A: Supplement 1

Retrospective reviews of serious spinal cord injury in RU

Study	Region	Study Period	Incidence data
Armour et al.[1]	New Zealand	1976 to 1995	n=119
Berry et al.[2]	NSW (Australia)	1986 to 2003	9.8 vs. 6.1COT per 100,000 player-years
Bohu et al.[3]	France	1996 to 1997	2.1 CSI per 100,000 per player/year
		2005 to 2006	1.4 per 100,000 per player/year
Burry and Gowland[4]	New Zealand	1973 to 1978	n=54
Carmody et al.[5]	Australia	1997 to 2002	3.2 ASCI per 100,000 players
Katoh et al.[6]	Japan	1990 to 1992	n=52
Kew et al.[7]	Cape Town	1963 to 1989	n=117
Noakes et al.[8]	Cape Province	1990 to 1997	n=67
Quarrie et al.[9]	New Zealand	1976 to 2005	n=77
		2000	3.9 SI per 100,000 players/year
		2005	0.7 SI per 100,000 players/year
Rotem et al.[10]	NSW (Australia)	1984 to 1996	n=56
		1984 to 1987	1.6 CSCI per 10,000 participants
		1988 to 1991	1.4 CSCI per 10,000 participants
		1992 to 1996	1.2 CSCI per 10,000 participants
Scher[11]	Cape Province	1964 to 1976	n=20
Scher[12]	Cape Province	1985 to 1989	n=40
Silver and Stewart[13]	England	1965 to 1982	n=63
		1982 to 1987	n=19
		1987 to 1993	n=11
Sovio[14]	British Columbia	1975 to 1982	n=9
Spinecare Foundation[15]	Australia	1986 to 1996	3.5 ASCI per 100000 players
Taylor and Coolican[16]	Australia	1960 to 1976	n=7 SCI
		1977 to 1985	n=30 SCI
Williams and McKibbin[17]	Wales	1964 to 1984	N=30 UCSI

CSI: Cervical spine injury; COT: Cases of tetraplegia; ASCI: Acute spinal cord injury: SI: Spinal injury; CSCI: Cervical spinal cord injury; UCSI: Unstable cervical spine injuries.

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Appendix A: Supplement 2

List of excluded articles – Articles are listed in the systematic order of exclusion. They may have also been excluded on secondary components of the selection criteria which is not stated in this table.

Study	Year	Reason for Exclusion
Articles that did not meet selection criteria A		
Adams[1]	1977	Retrospective cohort
Andrews et al[2]	2008	Retrospective case review
Armour et al[3]	1997	Retrospective case review
Babic et al[4]	2001	Retrospective questionnaire
Beazell[5]	1998	Case report
Berge et al[6]	1999	Cross sectional study
Berry et al[7]	2006	Retrospective case review
Blignaut et al[8]	1987	Cross sectional study
Bohu et al[9]	2009	Retrospective cohort
Briscoe[10]	1985	Retrospective cohort
Browne[11]	2006	Retrospective case series
Burry and Gowland[12]	1981	Retrospective review
Carmody et al[13]	2005	Retrospective review
Cassell et al[14]	2003	Retrospective review
Castel et al[15]	2001	Case report
Chaudhry and Hajarnavis[16]	2003	Case report
Comstock and Fields[17]	2005	Cross sectional study
Cooney et al[18]	2000	Cross sectional study
Crook and Eynon[19]	2005	Case report

Davidson et al[20]	1978	Retrospective cohort
Davidson[21]	1987	Retrospective cohort
Davies and Kaar[22]	1993	Case report
de Beer et al[23]	1990	Case report
Dearing[24]	2006	Case report
Dineen and Gallagher[25]	1981	Retrospective review
Donaldson et al[26]	2004	Cross sectional study
Durkin[27]	1977	Retrospective survey
Dyer[28]	1991	Case report
Elias et al[29]	2007	Case report
Finch et al[30]	1998	Retrospective review
Franks et al[31]	1978	Case report
Fuller et al[32]	2007	Cross sectional study
Fuller and Ward[33]	2008	Cross sectional study
Gemmell and Dunford[34]	2007	Cross sectional study
Gerrard et al[35]	1994	Retrospective cohort
Gianotti et al[36]	2008	Retrospective review
Gianotti et al[37]	2009	Retrospective review
Hoskins[38]	1979	Retrospective review
Jones et al[39]	2005	Case report
Katoh et al[40]	1996	Retrospective review
Kemp and Targett[41]	1999	Case report
Kew et al[42]	1991	Retrospective review
Lark and McCarthy[43]	2007	Cross sectional study
Lark and McCarthy[44]	2009	Cross sectional study
Lee et al[45]	2001	Retrospective follow-up
Leigh-Smith et al[46]	2005	Case report
Maxwell and Visek[47]	2009	Cross sectional study

McCoy et al[48]	1984	Case series
McKenna et al[49]	1986	Retrospective review
Milburn[50]	1987	Experimental study
Milburn[51]	1994	Experimental study
Miyamoto et al[52]	2004	Case report
Noakes et al[53]	1999	Retrospective review
O'Brien[54]	1992	Retrospective survey
O'Brien[55]	1996	Case report
O'Carroll et al[56]	1981	Retrospective cohort
O'Connell[57]	1954	Retrospective case review
Olivier et al[58]	2008	Cross sectional study
O'Rourke et al[59]	2007	Retrospective cohort
Palmer et al[60]	1995	Case study
Peek and Gatherer[61]	2005	Case study
Pringle et al[62]	1998	Cross sectional study
Quarrie et al[63]	2007	Retrospective review
Quarrie et al[64]	1996	Cross sectional study
Quarrie et al[65]	1995	Cross sectional study
Quarrie et al[66]	2008	Retrospective review of video records
Reid and Trent[67]	2002	Case report
Rotem et al[68]	1998	Retrospective review
Scher[69]	1977	Retrospective case series
Scher[70]	1981	Case report
Scher[71]	1982	Case report
Scher[72]	1983	Case report
Scher[73]	1983	Case report
Scher[74]	1983	Case report

Scher[75]	1983	Case report
Scher[76]	1990	Case report
Scher[77]	1990	Cross sectional study
Scher[78]	1991	Retrospective cohort
Scher[79]	1991	Retrospective cohort
Scher[80]	1991	Retrospective cohort
Secin et al[81]	1999	Retrospective review
Shelly et al[82]	2006	Retrospective review
Silver[83]	1993	Retrospective review
Silver[84]	1984	Retrospective review
Silver[85]	1992	Retrospective review
Silver[86]	1988	Retrospective review
Smith and Sparkes[87]	2004	Retrospective cohort
Sovio et al[88]	1984	Retrospective cohort
Sparks[89]	1981	Retrospective cohort
Spinecare foundation[90]	2003	Retrospective cohort
Takakuwa et al[91]	1994	Case report
Tasca et al[92]	2008	Case report
Taylor and Coolican[93]	1987	Retrospective review
Thakore et al[94]	2008	Case report
Vikramaditya and Pritty[95]	2001	Case report
Walkden[96]	1975	Retrospective review
Weightman and Browne[97]	1974	Retrospective survey
Weir and Watson[98]	1996	Retrospective survey
Wetzler et al[99]	1996	Retrospective cohort
Wetzler et al[100]	1998	Retrospective review
Williams and McKibbin[101]	1978	Retrospective review
Williams and McKibbin[102]	1987	Retrospective review

Yard and Comstock[103]	2006	Retrospective review

Articles that did not meet selection criteria B

Torg et al[104]	1985	no RU specific data

Articles that did not meet selection criteria C

Abernethy and MacAuley[105]	2003	No neck specific data
Alsop et al[106]	2000	No neck specific data
Alsop et al[107]	2005	No neck specific data
Bedford and Bedford[108]	1984	No neck specific data
Best et al[109]	2005	No neck specific data
Boyce and Quigley[110]	2003	No neck specific data
Brooks et al[111]	2005	No neck specific data
Brooks et al[112]	2008	No neck specific data
Castinel et al[113]	2008	No neck specific data
Clark et al[114]	1990	No neck specific data
Collins et al[115]	2008	No neck specific data
Fuller et al[116]	2008	No neck specific data
Fuller et al[117]	2007	No neck specific data
Garraway and Macleod[118]	1995	No neck specific data
Garraway et al[119]	1999	No neck specific data
Havkins[120]	1986	No neck specific data
Inglis and Stewart[121]	1981	No neck specific data
Jones et al[122]	2001	No neck specific data
Kauffman[123]	1985	No neck specific data
Lee and Garraway[124]	1996	No neck specific data
Lee et al[125]	1997	No neck specific data

MacLeod[126]	1992	No neck specific data
Micheli and Riseborough[127]	1974	No neck specific data
Myers[128]	1980	No neck specific data
Quarrie et al[129]	2001	No neck specific data
Quarrie et al[130]	1996	No neck specific data
Roux et al[131]	1987	No neck specific data
Roy[132]	1974	No neck specific data
Seward et al[133]	1993	No neck specific data
Sharp et al[134]	2001	No neck specific data
Stewart and Burden[135]	2004	No neck specific data
Stokes et al[136]	1994	No neck specific data
Upton et al[137]	1996	No neck specific data
Watson[138]	1981	No neck specific data
Watson[139]	1984	No neck specific data
Watson[140]	1995	No neck specific data
Watters et al[141]	1984	No neck specific data
Wilson et al[142]	1999	No neck specific data
Articles that did not meet selection criteria D		
Lee et al[143]	2001	Re-published neck injury data
Wekesa et al[144]	1994	Re-published neck injury data

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Appendix A: Supplement 3

Comparison where possible of injury rate between injury definition groups

First Author & Year	Injury definition group Sub-population	Match injury rate	Training injury rate
Brooks, J.[1] 2005	Fully inclusive time-loss Professional men	**Forwards** ^8.75 (CI: 6.75, 11.25) /1000 player hours match exposure **Backs** ^3.75 (CI: 2.50, 5.00) /1000 player hours match exposure	
Brooks, J.[2] 2005	Fully inclusive time-loss Professional men		**Forwards** ^0.04 (CI: 0.01, 0.10) /1000 (unspecified) player hours **Backs** ^0.03 (CI: 0.00, 0.08) /1000 (unspecified) player hours
Fuller, C.W.[3] 2007	Fully inclusive time-loss Professional men	Incidence rate: 6.46 (CI: 5.31-7.86) /1000 player match hours.	Incidence rate: 0.06 (CI: 0.03-0.11) /1000 player training hours.
Fuller, C.W.[4] 2008	Fully inclusive time-loss Professional men	4.2 (CI: 2.1, 8.3) /1000 playing hours	0.1 (CI: 0.0, 0.4) /1000 playing hours
Holtzhausen, L.J.[5] 2006	All inclusive Professional men	1.4* /1000 game hours	0.4*/1000 training hours
Kerr, H.[6] 2008	All inclusive Amateur men	0.43* /1000 player game-hour	0.41* /1000 practice athletic exposures

* Confidence intervals not reported

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Appendix A: Supplement 4

Summary table of extracted risk factors with supportive data

STUDY	RISK FACTOR
First Author & Year	**Neck injury specific risk factor identified and specified based upon the study data**
Addley, K.[1] 1988	Nil
Bathgate, A.[2] 2002	Nil
Bird, Y.[3] 1998	1. Forwards have higher incidence of neck injury in games (x^2, P=0.025) 2. Game neck injury incidence was higher than practice.
Bottini, E.[4] 2000	1. Young players had a greater risk of suffering either a muscle or ligament injury of the cervical column (OR=3.0; 95% CI 1.05 to 10.08; P=0.04)
Brooks, J.[5] 2005	1. The incidence of most neck and spinal injuries was significantly higher for forwards then for backs 2. Front row had a greater risk of neck injury than other forwards 3. Midfield backs (centres) tended to experience more collisions than the other backs, this may explain the higher level of absences from cervical nerve root injuries experienced by outside backs 4. Cervical nerve root injuries were common in head on tackles
Brooks, J.[6] 2005	Nil

Carson, J.D.[7] 1999	Nil
Dalley, D.R.[8] 1982	1. Late teen and senior players were at higher risk (incidence) of neck injury
Dalley, D.R.[9] 1992	1. Neck injury incidence was higher in forwards than backs
Davies, J.E.[10] 1978	1. Head and neck injuries were significantly more common when play was static than when players were running (x^2=5.31; P<0.05) 2. Head and neck injuries together were significantly more common on wet than dry pitches (x^2=6.8; P<0.01)
Doyle, C.[11] 2004	Nil
Durie, R.M.[12] 2000	Nil
Fuller, C.W.[13] 2007	1. The incidence of match injuries was significantly higher for forwards than for backs (P<0.01) 2. There were significant differences between the numbers of injuries sustained in each quarter of the game (cervical: P = 0.02), with a trend for the overall incidence of spinal injuries to increase as matches progressed 3. Compared with early-season, the incidence of match injuries sustained in the cervical region of the spine increased as the season progressed (early-season: 4.45, CI: 3.03–6.54; mid-season: 6.36, CI: 4.47–9.04, P = 0.16; late season: 11.02, CI: 8.08–15.02, P<0.01) 4. There were no significant differences in the overall incidence

and severity of spinal injuries sustained during matches for forwards or backs as a function of player's age, stature, body mass, or body mass index

5. There were no significant difference (P = 0.73) in the overall incidence of spinal injuries sustained in matches by players ''wearing'' (10.34; CI: 7.04 to 15.19) and ''not wearing'' headgear (11.12; CI: 9.43–13.11)
6. There were no significant difference between the incidence (P = 0.47) of spinal injuries sustained by front-row forwards during scrummaging when they were playing ''in'' (incidence: 9.85, CI: 6.75–14.36) or ''out of'' (incidence: 14.44, CI: 5.42–38.47) their normal playing positions
7. Most cervical spine injuries sustained during scrummaging occurred to a facet joint (38%), whereas cervical spine injuries sustained during a tackle were more likely to involve a nerve root (49%)
8. The overall incidence of training injuries was significantly (P<0.01) lower than that for match injuries. The incidence of training injuries for forwards was significantly (P=0.02) greater than that for backs
9. The average severity of all spinal injuries sustained during training was significantly greater (P = 0.04) than that for matches
10. More injuries were sustained during weight training than any other training activity (weights: 24, 33%; running: 9, 13%; tackle: 8, 11%)
11. The most common injury diagnoses associated with each type

		of training activity were: contact rugby skills–cervical nerve root (5 of 20; 25%)
Fuller, C.W.[14] 2008	Nil	
Garraway, W.M.[15] 2000	Nil	
Holtzhausen, L.J.[16] 2006	Nil	
Hughes, D.C.[17] 1994	1.	The scrum may be a cause of cervical spine degeneration in front row forwards
Jakoet, I.[18] 1998	Nil	
Junge, A.[19] 2004	Nil	
Kerr, H.[20] 2008	Nil	
Lewis, E.R.[21] 1996	1.	Women suffered fewer injuries to the neck compared to men and youth
Lingard, D.A.[22] 1976	1.	Forwards had a disproportionately higher number of minor neck injuries (x^2=11.1, P<0.001)
Marshall, S.W.[23] 2002	1.	With regards to worn protective equipment: neck injury (sprain/strain) incidence was lower in partially protected American football players when compared to RU
McIntosh, A.S.[24] 2008	1.	The analysis of game injuries to the neck showed a significant association with player position and injury. The front row had the greatest rate of injury and the backs had a significantly lower rate of neck injury compared to the front row as reference

	2. All missed game neck injuries occurred to forwards; due to this and the low absolute number of injuries, a statistical analysis was not possible 3. No significant differences were observed based on analyses of grade or level for neck injuries at games
McManus, A.[25] 2004	Nil
Nathan, M.[26] 1983	1. Hookers were likely to suffer from neck injury while scrummaging
Reilly, T.[27] 1981	Nil
Ryan, J.M.[28] 1992	Nil
Schick, D.[29] 2008	1. Women RU players may have a higher incidence of neck injury than male counterparts
Sparks, J.[30] 1985	1. Front row forwards suffered the most neck injuries and the set scrum was responsible for many of these
Targett, S.G.[31] 1998	Nil
Underhill, J.[32] 2007	1. Female had a significantly higher percentage of RU neck injury than their male counterparts ($P<0.05$)
Wekesa, M.[33] 1996	Nil

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Appendix B

Final Ethics approval letter, Ethics Review Committee (Human Ethics) Macquarie University (reference number: HE24FEB2006-M04460)

MACQUARIE
UNIVERSITY ~ SYDNEY

Mr Michael Swain
18 Hunter Avenue
St Ives NSW 2075

11 April 2006

Dear Mr Swain

FINAL APPROVAL LETTER

Title of Project: Neck injuries in rugby union: incidence, severity, aetiology and prevention. A prospective cohort study
Reference Number: HE24FEB2006-M04460

Thank you for your recent correspondence. Your responses have satisfactorily addressed the outstanding issues raised by the Committee. You may now proceed with your research. This approval is subject to the following condition:

1. Please provide evidence of the successful completion of a Working with Children Check for the chief investigator when available.

Please note the following standard requirements of approval:
1. Approval will be for a period of twelve months. At the end of this period, if the project has been completed, abandoned, discontinued or not commenced for any reason, you are required to submit a Final Report on the project. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. The Final Report is available at http://www.ro.mq.edu.au/ethics/human/forms.
2. However, at the end of the 12 month period if the project is still current you should instead submit an application for renewal of the approval if the project has run for less than five (5) years. This form is available at http://www.ro.mq.edu.au/ethics/human/forms If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report (see Point 1 above) and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).
3. Please remember the Committee must be notified of any alteration to the project.
4. You must notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that might affect continued ethical acceptability of the project.
5. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University (http://www.ro.mq.edu.au/ethics/human)).
6. If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide Macquarie University's Grants Officer with a copy of this letter as soon as possible. The Grants Officer will not inform external funding agencies that you have final approval for your project and funds will not be released until the Grants Officer has received a copy of this final approval letter.

ETHICS REVIEW COMMITTEE (HUMAN RESEARCH)
MACQUARIE UNIVERSITY (E11A)
SYDNEY, NSW, 2109 AUSTRALIA
Secretary: Ph: (02) 9850 7854 Fax: (02) 9850 8799 E-mail: kdesilva@vc.mq.edu.au
http://www.ro.mq.edu.au/eth_hum.htm

Yours sincerely

p.p. Associate Professor Richard Stevenson
Acting Chair, Ethics Review Committee (Human Research)

ETHICS REVIEW COMMITTEE (HUMAN RESEARCH)
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Appendix C

INFORMATION AND CONSENT FORM: RUGBY UNION PLAYER

Neck Injuries in Rugby Union

This study aims to identify the incidence and severity of neck injuries in rugby union football players. It aims to identify mechanisms that cause neck injuries. Once these mechanisms and aetiological factors are identified associated risk factors become apparent. This is known as the sequence of prevention. This information can lead to prevention or decreased severity of such injuries.

This study is being conducted by Mr. Michael Swain to meet the requirements of a Masters of Philosophy degree, undertaken at Macquarie University. It is being supervised by Dr Henry Pollard, from the Department of health and Chiropractic. You can contact us on:

Mr. Michael Swain: 0414929638, (02) 9983 0532 or mikeswain@unwired.com.au
Dr. Henry Pollard: (02) 9850 6385 or henry.pollard@mq.edu.au

We require a starting point that lets us know your health, sporting and injury status. This is obtained by you filling out a short five minute survey and performing a quick physical assessment of your neck function. There's no risk or discomfort. To accurately identify your exposure time to rugby we will provide you with a simple tick box sheet that you can record your participation at training and games though 2006. In the event you sustain a neck injury as a result of participation in rugby union we would like you to notify your club's physiotherapist or doctor in the normal manner, so that they may document the details of your injury and follow your injury progress. This will involve a history of how it was sustained and a physical exam of the affected area. This study will be conducted from the start of your pre-season training through to the end of your playing season. In the event you sustain an injury that goes beyond this, a follow up will be monitored. Participation in rugby union has inherent risks as it is a contact sport. Involvement in this study provides no additional risks whatsoever.

You will receive no direct reward from being involved in this study. The information you provide is privy only to your club's medical staff and the conductors of this study. The medical record of your neck injuries may be accessed as part of this study. If you choose to participate you are asked to sign the section below giving the chief investigator authority to seek injury details from your medical practitioner or other health worker as appropriate. At no time will your identity be made public. The information collected from you will be stored in a secure location at the office of your club's medical staff or at the office of the chief investigator. De-identified data results may be made available to other researchers on request. Feedback with results will be provided to your Club/School in the form of a summary report. If you would like a copy sent to you directly please contact Mr. Michael Swain. Your participation in this study is on a voluntary basis. You have the right to withdrawal from this study at anytime without reason or adverse consequence.

I ___________________________________ agree to participate in this research project. I do so under a voluntary basis, with the knowledge that I am free to withdrawal at anytime without reason or adverse consequence. I understand that if I am injured in a match the chief investigator has my permission to access the injury details from my health care worker.

Signed: _______________________________ Date: _____________________

Patient/Guardian: ______________________ Date: _____________________
(If under 18 years)

Witness: ______________________________ Date: _____________________

The participant has been given a signed copy of this consent form to keep for his records.

The ethical aspects of this study have been approved by the Macquarie University Ethics Review Committee (Human Research). If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Research Ethics Officer (telephone [02] 9850 7854, fax [02] 9850 8799, email: ethics@vc.mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome

Appendix D

The baseline data collection questionnaire

Neck injuries in rugby union – a prospective cohort study

Name: ____

Age: ________________ Alcohol Consumption (glasses/week): ___________

Occupation: ________________ Ethnic Origin: ______________________

1. How many years have you played Rugby Union: ______________________

2. Which statement best describes the current stage of your rugby career?

[ ] I don't believe I have yet reached my playing potential

[ ] I am currently playing rugby union at the peak of my potential

[ ] I have already past my playing peak, but continue to play for enjoyment

3. What is the likely position you will play this season? ____________________

4. What is the likely grade you will play at your club/school? ________________

5. How many **Weeks** of physical preparation have you undertaken prior to the commencement of the 2007 playing season? : __________________________

6. How many **Hours** per week? : ____________________________________

7. Please specify how you prepared: Weight training [ ] Running [ ] Boxing [ ] Rowing[ ] Cycling [ ] Ball handling [ ] Other [ ] Please describe: _____________

8. Do you currently have a neck injury? Yes [ ] / No [ ] if no proceed to question 10

9. Have you received treatment for this injury? No [ ] / Yes [ ]

Please describe (e.g. Physio) ______________________________________

10. Have you injured your neck before due to playing rugby union? Yes [ ] No [ ]

If Yes, How many times have you injured it? (Circle) 1 2 3 4 5 greater than 5

11. How severe was your last neck injury due to rugby union? (Please tick)

[ ] Able to return to game/training

[ ] Missed one week

[ ] Missed two weeks

[ ] Missed more than two weeks

12. Have you had your neck X-rayed before? No [ ] Yes [ ] When_____________

13. If Yes, Are you aware on any anomalies of your neck?

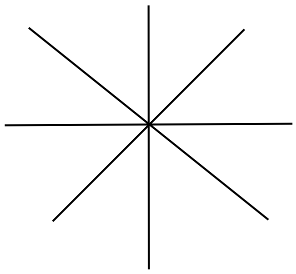
No [ ] Yes [ ] Describe ____________________________________

THANKYOU FOR YOUR TIME

Clinician use only

Cervical Range of Motion

	Flexion	Extension	Side-bend	Rotation
Normal limits	80-90	70	20-45	70-90
Players Range				



Comments

Cervical Strength Assessment

Shows ability to hold own body weight at an angle of 45 degrees on the **LEFT** side of the neck for a period of 10 seconds: **PASS [ ]** **FAIL [ ]**

Shows ability to hold own body weight at an angle of 45 degrees on the **RIGHT** side of the neck for a period of 10 seconds: **PASS [ ]** **FAIL [ ]**

Modified Jull's Test **PASS [ ]** **FAIL [ ]**

The ethical aspects of this study have been approved by the Macquarie University Ethics Review Committee (Human Research). If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Research Ethics Officer (telephone [02] 9850 7854, fax [02] 9850 8799, email: ethics@vc.mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome

Appendix E

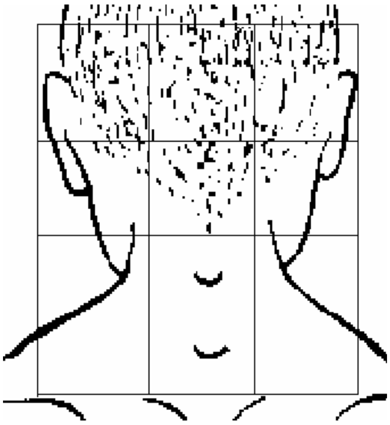
Data collection tool - Modified RUIRF

Player's Name: ____

1. Date: ________________2. Grade: ______________ 3. Age: _____________

4. Site of Injury:

Please shade area/s of pain.



If easier describe location:

____
____
____
____
____
____

5. Severity / Time lost (Circle): A) Return to play / Retired Injured

B) Time lost from sport: None / 1 week / 2 weeks / More ______________________

6. Mechanism of injury/Forces: (Circle) A) Intrinsic / Extrinsic

Where Known- B) Flexion / Extension / Rotation / Side bend Rotation / Compression

7. Where (Circle): Game / Training

8. Phase of Play/Training (Circle): Scrum / Lineout / Ruck / Maul / Tackle / Kicking / Pileup / Collision / Other___________

9. Terrain (circle): Hard / Soft / Muddy / Other _______________

10. Weather (Circle): Hot / Cold / Wet / Other ________________

11. Time of Game (circle): 1st Half / Second Half / Time on

12. Relationship of ball and injured player (circle): Near Ball / Behind Play

13. Play (circle): Legal / Illegal

14. Position: LHP / H / THP / LL / RL / LF / RF / 8 / HB / 5/8 / LW / IC / OC / RW / FB

15. Classification of injury

Assessment

Symptoms | Physical Findings

OSICS Classification: ____

Treatment/Modalities. (Nature/Duration/Costs)

Instruction to player/carer

Referred to

Time lost from
Sport: ____
Work/School: ____

Appendix F

Orchard Sports Injury Classification System – Version 8
(OSCIS-8)

OSICS codes version 8

Head and neck soft tissue trauma

HHO	eye haematoma
HHS	scalp haematoma
HHN	nose haematoma
HHM	mouth hameatoma
HHE	ear haematoma
HH1	Head/facial haematoma
HK1	Scalp laceration/abrasion
HK2	Facial laceration/abrasion
HKN	nose laceration
HKM	mouth laceration
HKJ	chin laceration
HKF	forehead laceration
HKE	eyelid laceration
HKC	cheek laceration
HKB	eyebrow laceration
HV1	Epistaxis (nosebleed)
NH1	Neck haematoma
NK1	Neck laceration/abrasion

Eye injuries

HOF	eye foreign body
HOH	hypheama
HO1	Eye injury/trauma
HOU	corneal abrasion
HOL	contact lense displacement
HOR	retinal detachment

Concussion

HN1	Concussion
HN2	Intracranial bleed
HN3	Chronic brain injury
HN4	Cranial nerve injury
NN4	Spinal cord concussion

Facial bone fractures

HF1	Nose fracture
HF3	Mandible fracture
HF4	Fractured facial bone
HFM	fractured maxilla
HFZ	fractured zygoma
HFE	fractured orbital socket
HG1	Avulsed/fractured tooth
HGF	tooth fracture
HGA	tooth avulsion

Other head organ damage

HI1	Otitis externa
HI2	Cellulitis/skin infection, face
HO2	Perforated eardrum
NO1	Laryngeal trauma
NN1	Cervical nerve root compression/stretch
NN2	Neck spinal injury

Skull and neck fractures

HFF	fractured frontal bone
HF2	Skull fracture
NF1	Stable cervical fracture
NF2	Unstable cervical fracture
NG1	Avulsion fracture cervical spine (e.g. spinous process)

Jaw sprains

HD1	Disl temporomandibular jt
HJ1	Spr temporomandibular jt

Head and neck muscle strains

HY1	Facial muscle trigger pts
NM1	Neck muscle strain
NY1	Neck muscle trigger pts/spasm/torticollis

Neck sprains

NL1	Neck ligament injury
NC1	Cervical disc prolapse
NC2	Cervical disc degeneration
NU8	Recurrent vertebral subluxation
NJ1	Whiplash/neck sprain
NP1	Cervical facet joint pain
NA1	Cervical facet jt degenerative arthritis
NB1	Cervical developmental anomaly
NN3	Cervical spinal canal stenosis
NZ1	Neck pain undiagnosed

Shoulder sprains and dislocations

SDA	Antero-inferior shoulder dislocation
SDI	Inferior shoulder dislocation
SDP	Posterior shoulder dislocation
SD1	Dislocated shoulder
SUP	Posterior shoulder subluxation
SUI	Instability-related impingment
SUA	Antero-inferior shoulder subluxation
SU1	Shoulder subluxation/ chronic instability
SCS	SLAP lesion
SCH	HAGL lesion
SCP	Posterior labral lesion
SCB	Bankhart lesion, labrum
SC1	Shoulder chondral lesion
SJ1	Shoulder jt sprain
SP1	Adhesive capsulitis or frozen or stiff shoulder
SA1	Shoulder jt degenerative arthritis
SLI	Glenohumeral ligament tear
SL1	Shoulder ligament sprain/tear
SZ1	Shoulder pain undiagnosed

A-C (acromioclavicular) joint

SD2	Acromioclavicular jt disl (Grade 3)
SJ2	Acromioclavicular jt sprain
SAO	osteolysis distal clavicle
SA2	Acromioclavicular arthritis/ distal clavicle osteolysis
SAA	arthritis, A/C joint

Fractured clavicles

SFO	clavicle fracture, outer third
SFR	clavicle, refracture through callus
SFM	clavicle fracture, mid-third
SFI	clavicle fracture, inner-third
SF1	clavicle fracture

Shoulder tendon injuries

STD	Acute Subacromial Impingement
STE	Acute Posterior Internal Impingement
STC	Chronic Anterior Internal Impingement
STB	Chronic Posterior Internal Impingement
ST1	Rotator cuff tendon pathology
STS	Supraspinatus tendon injury
STA	Chronic Subacromial Impingement
STU	Subscapularis tendon injury
STF	Acute Anterior Internal Impingement
STI	Infraspinatus tendon injury
ST2	Biceps tendinitis
SRI	Infraspinatus tendon rupture
SR1	Rotator cuff tendon rupture/large tear

SRS	Supraspinatus tendon rupture
SRU	Subscapularis tendon rupture
SR2	Rupture of long head of biceps tendon
CR1	Pectoralis major tendon rupture
SR3	Pectoralis major tendon rupture
UR1	Pectoralis major tendon rupture

Other arm and elbow fractures

SF2	scapula fracture
SF3	fracture, neck of humerus
SGH	Hill-Sachs lesion
SGB	Bankhart lesion, bony
SG1	Avulsion fracture shoulder
SGS	Avulsion supraspinatus insertion
SS1	Stress fracture coracoid process
UF1	fracture, shaft of humerus
EF1	Supracondylar fracture humerus
EF2	fractured humerus condyle(s)
EF3	fractured head of radius or olecranon
EG1	Elbow avulsion fracture

Shouler and arm stress fractures

US1	Humerus stress fracture
ES1	Elbow stress fracture

Shoulder and arm neurovascular

SB1	Cervical rib
SN1	Brachial plexus traction injury/burner/stinger
SN2	Axillary nerve palsy
SN3	Nontraumatic brachial plexus lesion (incl thoracic outlet)
SV1	Axillary vessel thrombosis/insufficiency
SN4	Suprascapular nerve entrapment or palsy
UN1	Upper arm nerve injury
UNM	Medial nerve injury, upper arm
UNR	Radial nerve injury, upper arm
EN1	Ulnar neuropathy, elbow
EN2	Other nerve entrapment, elbow

Upper arm muscle strains

SM1	Muscle strain, shoulder region
SML	Latissimus dorsi muscle strain
SMP	Pectoralis major muscle strain
SY1	Shoulder trigger pts/ posterior muscle soreness
UMT	Triceps muscle strain
UMB	Biceps muscle strain
UM1	Upper arm muscle strain
UY1	Upper arm muscle soreness/ trigger pts

Forearm fractures

RFD	Fractured radius, distal, undisplaced
RFR	Radial fracture, minimally displaced
RF1	Fractured forearm bone(s)
RFC	Colles fracture radius
RMG	Galeazzi fracture (radius) dislocation r/u joint
RFM	Monteggia fracture (ulna) dislocation radial head
RFS	Smith fracture radius
RFU	Ulna fracture, minimally displaced
RFB	Fractured radius and ulna shafts
RFE	Fractured radius distal epiphysis
WF3	Intraarticular # radius

Shoulder and arm soft tissue trauma

SHD	Deltoid haematoma
SH1	Shoulder haematoma
SK1	Shoulder laceration/abrasion
UHB	Biceps haematoma
UHM	Myositis ossificans, upper arm
UHT	Triceps haematoma
UH1	Upper arm haematoma
UK1	Upper arm laceration/abrasion
EH1	Elbow haematoma
EK1	Elbow laceration/ abrasion

Elbow sprains or joint injuries

EDA	Elbow dislocation anterior
ED1	Dislocated elbow
EDP	Elbow dislocation posterior
ED2	Disl head of radius (including pulled elbow)
EU1	Elbow valgus instability
EU2	Elbow posterolateral instability
EC1	Chondral lesion elbow (+/- loose bodies)
ECO	Elbow osteochondritis dissecans
ECL	Loose body, elbow joint
EJ1	Sprained/jarred elbow
EP1	Elbow atraumatic synovitis
EA1	Elbow jt degenerative arthritis
EL1	Elbow medial collateral ligament strain or tear
ET4	Elbow joint impingement
EZ1	Elbow pain undiagnosed

Elbow tendon injuries

ER1	Biceps tendon distal rupture
ET1	Tennis elbow (lateral epicondylitis)
ET2	Golfer's elbow (medial epicondylitis)
ER2	Triceps tendon rupture
ET3	Olecranon bursitis/ apophysitis/triceps tendinitis

Scaphoid fractures

WFP	Proximal scaphoid fracture
WF1	Fractured scaphoid
WFD	Distal fracture scaphoid
WFW	Waist fracture scaphoid
WQ1	Non-union scaphoid fracture

Other wrist and hand fractures

WFH	Fractured hamate
WFT	Fractured trapezium
WF2	fracture, other carpal bone
WGH	Fractured hook of hamate
WGR	Fractured radial styloid
WGU	Fractured ulna styloid
WG1	Wrist avulsion fracture
WS1	Radial epiphysis lesion or carpal stress fracture
PF1	Bennett's fracture
PFR	Rolando fracture
PFA	First metacarpal shaft fracture
PF2	Metacarpal fracture
PFX	Multiple metacarpal fractures
PFB	Second metacarpal fracture
PFC	Third metacarpal fracture
PFD	Fourth metacarpal fracture
PFE	Fifth metacarpal fracture
PFG	Second proximal phalanx fracture
PFU	Multiple phalangeal fractures
PFF	First proximal phalanx fracture
PF3	Fractured phalanx
PFS	Fourth distal phalanx fracture
PFM	Third middle phalanx fracture
PFQ	Third distal phalanx fracture
PFP	Second distal phalanx fracture
PFH	Third proximal phalanx fracture
PFI	Fourth proximal phalanx fracture
PFJ	Fifth proximal phalanx fracture
PFK	First distal phalanx fracture
PFL	Second middle phalanx fracture
PFO	Fifth middle phalanx fracture
PFN	Fourth middle phalanx fracture
PFT	Fifth distal phalanx fracture
PG1	Avulsion fracture phalanx
PQ1	Malunion finger fracture

Forearm and hand stress fractures

RS1	Stress fracture radius or ulna

Forearm and hand soft tissue trauma

RH1	Forearm haematoma
RK1	Forearm laceration/ abrasion
RK2	Forearm skin lesion
WH1	Wrist haematoma
WK1	Wrist laceration/ abrasion
PH1	Hand haematoma
PH2	Subungual haematoma/ fingernail problem
PK1	Hand/finger laceration/abrasion
PK2	Hand/finger blisters/ contact dermatitis/callus
PI1	Hand/finger infection

Forearm and hand neurovascular

WN1	Wrist nerve compression
WNC	Carpal tunnel syndrome
WV1	Aneurysm of vessel near wrist
PP2	Hand Reflex Sympathetic Dystrophy

Hand tendon injuries

RM1	Forearm muscles strain
RY1	Forearm muscle trigger pts
RT1	Extensor tenosynovitis/ intersection syndrome
WT1	Extensor tenosynovitis/de Quervain's disease
WT2	Wrist ganglion
WT3	Flexor tenosynovitis
WR1	Tendon rupture, wrist
WRE	Ruptured extensor pollicus longus tendon
PT1	Trigger finger
PT2	Hand tendinitis
PRC	Ruptured fourth extensor tendon
PRA	Ruptured second extensor tendon
PRD	Ruptured fifth extensor tendon
PR1	Ruptured finger tendon
PRB	Ruptured third extensor tendon
PRT	Ruptured third flexor tendon
PRF	Ruptured fourth flexor tendon

Wrist and hand sprains and dislocations

RB1	Radio-ulnar variance
WD1	Dislocated carpus
WD2	First CMC joint dislocation
WUD	Scapholunate instability
WUV	VISI wrist instability
WU1	Carpal instability
WU2	Distal radioulnar joint instability
WC1	Wrist fibrocartilage tear
WJ1	Sprained/jarred wrist jt
WJ2	Distal radioulnar jt sprain
WP1	Wrist jt synovitis (including impingement syndrome)
WA1	Wrist osteoarthritis (including avascular necrosis)
WAS	SLAC wrist arthritis
WL1	Carpal ligament tear
WLS	Scaphoid lunate ligament tear
WT4	Carpal boss
WZ1	Wrist pain undiagnosed
PDE	Fifth MCP joint disloation
PD1	Disl metacarpophalangeal or interphalangeal jt
PDA	First MCP joint dislocation
PDB	Second MCP joint dislocation
PDF	First IP joint dislocation
PDG	Second PIP joint dislocation
PDH	Third PIP joint dislocation
PDI	Fourth PIP joint dislocation
PDN	Fifth DIP joint dislocation
PDM	Fourth DIP joint dislocation
PDD	Fourth MCP joint dislocation
PDJ	Fifth PIP joint dislocation
PDK	Second DIP joint dislocation
PDC	Third MCP joint dislocation
PDL	Third DIP joint dislocation
PU1	Chronic jt instability of finger or thumb
PJ1	Spr metacarpophalangeal or interphalangeal jt
PP1	Finger joint chronic synovitis
PP3	Thumb sesamoiditis
PA1	Finger degenerative arthritis
PL1	Spr ulnar collateral ligament (Skier's) thumb
PL2	Other hand or finger ligament tear

Rib fractures

CFL	Fractured lower rib (9-12)
CFH	Fractured upper rib (1-4)
CFM	Fractured middle rib (5-8)
CF1	Fractured rib(s)
CFX	Fractured multiple ribs
CF2	Fractured sternum
OG2	Avulsion rib

Rib and costochondral bruising

CG1	Chest avulsion injury
CC1	Costal cartilage/ costochondral jt injury
CM2	Chest muscle strain
CT1	Intercostal tendonitis
CH1	Bruised ribs/chest wall (excluding sternum)
CH2	Bruised sternum
OG3	Avulsion iliac crest

Abdominal and thoracic organ damage

CO1	Pneumo-/haemo-thorax
CZ1	Chest pain undiagnosed
OH1	Abdominal haematoma
OO1	Abdominal trauma to internal organs
OOB	Bladder trauma
OOI	Intensitinal trauma
OOK	Kidney trauma
OOL	Liver trauma
OOP	Pancreas trauma
OOS	Spleen trauma
OZ1	Abdominal pain undiagnosed
DK2	Upper back skin lesion
DZ1	Thoracic pain undiagnosed
GH2	Testicular/scrotal haematoma
GOT	Ruptured testicle
GO1	Damage to pelvic organ
GOU	Ruptured urethra/penis

Lumbar and thoracic fractures

DF1	Fractured thoracic vertebrae
DG1	Fractured thoracic transverse or spinous process
LF1	# lumbar vertebrae
LGM	Fractured multiple transverse processes
LGB	Fractured transverse process L4
LGA	Fractured transverse process L1
LGC	Fractured transverse process L3
LG1	# lumbar transverse or spinous process
BF1	Fractured sacrum/coccyx

Rib stress fractures

CS1	Stress fracture rib(s)

Lumbar and thoracic soft tissue trauma

DH1	Thoracic back haematoma
LH1	Lumbar haematoma
LK1	Lumbar laceration/ abrasion
BH1	Buttock haematoma
BK1	Buttock laceration/ abrasion

Lumbar and thoracic sprains

CJ1	Sternoclavicular jt injury
DC1	Thoracic disc prolapse
DJ1	Thoracic facet jt sprain
DP1	Chronic thoracic facet jt pain/stiffness
DA1	Thoracic facet jt degenerative arthritis
DT1	Scheuermann's disease
DB1	Thoracic scoliosis
LCT	Disc injury L3/4
LCS	Disc injury L5/S1
LCF	Disc injury L4/5
LC1	Disc prolapse/disruption
LC2	Disc degeneration
LC3	Disc annular tear
LJ1	Lumbar facet jt strain/jar
LP1	Chronic lumbar facet joint pain (including referred)
LA1	Lumbar facet jt degenerative arthritis
LL1	Lumbar region ligament sprain
LB2	Lumbar scoliosis
LB3	Other lumbar anomaly (e.g. spina bifida occulta)
LN1	Lumbar spinal injury
LNS	S1 nerve root impingement
LNF	L4 nerev root impingement
LNL	L5 nerve root impingement
LN2	Lumbosacral nerve root impingement
LN3	Lumbar spinal canal stenosis
LN4	Lumbosacral nerve stretch/traction injury
LZ1	Lumbar pain undiagnosed
BP1	Sacroiliac joint pain (including spondyloarthropathies)
BP2	Sacrococcygeal jt pain
BZ1	Buttock pain undiagnosed

Lumbar stress fractures

LSE	Fractured pars interarticularis L4
LSP	Fractured pedicle lumbar vertebra
LSU	Fractured pars interarticularis L1-L3
LSF	Fractured pars interarticularis L5
LS1	Stress # lumbar spine
LS2	Lumbar stress reaction
LS3	Pedicle stress fracture
LQ1	Nonunion lumbar fracture
LBT	Spondylolysthesis grade 3
LBB	Bilateral spondylolysis
LBF	Spondylolysthesis grade 1
LBS	Spondylolysthesis grade 2
LB1	Spondylolisthesis/lysis

Abdominal and lumbar muscle strains

CM1	Chest muscle strain
CY1	Chest muscle trigger pts
OG1	Avulsion iliac crest
OM1	Abdominal muscle str
OMT	Transversus abdominus muscle strain
OMR	Proximal rectus abdominus strain
OMO	Abdominal oblique muscle strain
OM2	Bowler's side strain
OY1	Abdominal muscle trigger pts or spasm or winding
OT2	Costolliac impingement
DM1	Thoracic extensor muscle str
DY1	Thoracic back trigger pts
LM1	Lumbar muscle str
LY1	Lumbar trigger pts or muscle spasm
BM1	Gluteal muscle str/tear
BY1	Gluteal muscle or piriformis trigger pts

Hip joint injuries

GD1	Dislocated hip jt
GCL	Labral tear, hip joint
GC1	Hip chondral lesion
GJ1	Hip joint sprain/jar
GP1	Hip joint synovitis
GA1	Hip jt osteoarthritis/ avascular necrosis
GA3	Perthes' syndrome
GB1	Congenital dislocation hip
GI2	Hip joint infection

Groin and thigh stress fractures

GS2	Stress # neck of femur
GS3	Pelvic bone stress #
TS1	Stress # shaft of femur

Hip and groin haematomas

GH1	Haematoma, hip region
GK1	Groin laceration or abrasion
TK1	Thigh laceration/abrasion

Groin strain injuries

OT1	Rectus abdominus tendinitis
GS1	Osteitis pubis
GSI	Pubic symphysis instability
GM1	Hip flexor (including psoas) muscle str/tear
GMA	Proximal adductor strain
GMP	Iliopsoas muscle strain
GM8	Groin muscle str (unspecified)
GY1	Groin soreness or trigger points
GYA	Proximal adductor trigger points
GYP	Iliopsoas trigger points
GYR	Rectus abdominus trigger points
GT1	Adductor tendinopathy/tear
GR1	Rupture adductor longus origin
GT2	Sports hernia/abdominal tendinopathy
GT3	Iliopsoas tendinopathy/bursitis
GT4	Trochanteric bursitis
GZ1	Groin pain undiagnosed
TM3	Adductor muscle str/tear (incl. sartorius)
TMA	Distal adductor strain

Pelvic and thigh fractures

BG1	Avulsion # ischial tuberosity
GF1	# neck of femur
GF2	# pelvic ring
GF3	# ilium
GGA	Avulsion adductor from pubis
GGH	Avulsion hamstring from ischium
GGO	Avulsion from iliac crest
GGR	Avulsion rectus femoris from AIIS
GGS	Avulsion sartorius from ASIS
GG1	Pelvic avulsion # (iliac spines and pubic rami)
GA2	Slipped capital femoral epiphysis
TF1	# shaft of femur

Groin and thigh neurovascular

GNM	Meralgia parasthetica
GNI	Ilioinguinal nerve entrapment
GNG	Genitofemoral nerve entrapment
GN1	Nerve entrapment, groin region
GNO	Obturator nerve entrapment

Hamstring strains

BMG	Gluteal muscle strain
BMM	Adductor magnus strain
BYG	Gluteal trigger points
BYP	Piriformis trigger points
BYM	Adductor magnus trigger points
BT1	Ischial bursitis
BT2	Gluteal tendinitis/enthesopathy
BN1	Piriformis syndrome (with sciatic nerve impingement)
TMB	Biceps femoris strain
TMT	Distal medial hamstring strain
TM1	Hamstring strain/tear

TMS	Proximal (medial) hamstring strain
TYL	Lateral hamstring trigger points
TYM	Medial hamstring trigger points
TY1	Hamstring spasm/ cramps/trigger pts
TY3	Posterior thigh compartment syndrome
TR1	ruptured hamstring origin
BR1	ruptured hamstring origin
TZ1	Thigh pain undiagnosed
KTB	Lateral hamstring insertion tendonitis
KTL	Lateral gastrocnemius tendonitis
KTM	Medial gastrocnemius tendonitis
KTS	Medial hamstring insertion tendonitis
KT3	Posterior knee tendinitis/ bursitis
KR2	Ruptured hamstring distal insertion

Quadriceps strains

TMR	Rectus femoris strain
TM2	Quadriceps strain/tear
TMV	Vastus muscle strain
TYV	Vastus trigger points
TYR	Rectus femoris trigger points
TY2	Quadriceps spasm/cramps/ trigger pts/wasting

Thigh haematomas

THA	Arterial bleed, thigh
THH	Hamstring haematoma
THM	Myositis ossificans, thigh
TH1	Haematoma of thigh/ hamstrings
THV	Quadriceps haematoma

Knee - ACL (anterior cruciate ligament)

KD2	Dislocated knee
KLI	Incomplete tear, ACL
KL1	Anterior cruciate ligament strain/tear/rupture

Knee - MCL (medial ligament)

KL3	Knee medial collateral lig str/tear/rupture
KLM	Medial ligament grade 3 tear
KLP	Pellegrini-Steida syndrome

Knee - PCL (posterior cruciate ligament)

KL2	Posterior cruciate ligament strain/tear/rupture

Knee cartilage

KCU	Patellofemoral compartment chondral damage grade 3-4
KCN	Medial compartment chondral damage grade 3-4
KCM	Medial compartment chondral damage grade 1-2
KCK	Lateral compartment chondral damage grade 3-4
KCT	Patellofemoral compartment chondral damage grade 1-2
KC1	Knee articular cartilage damage
KCL	Lateral compartment chondral damage grade 1-2
KCB	Bucket handle tear medial meniscus
KC2	Medial meniscus tear
KCP	Posterior horn tear medial mensicus
KCH	Parrot beak tear lateral meniscus
KC3	Lateral meniscus tear
KCR	Radial tear lateral meniscus
KCX	Posterior horn tear lateral meniscus
KC4	Knee osteochondritis (+/- loose bodies)
KC8	Knee joint cartilage injury (unspecified)
KAG	Knee osteoarthritis, generalized
KA1	Knee jt degenerative arthritis
KB2	Discoid meniscus

Knee and patellar tendon injuries

KT1	Iliotibial band syndrome
KT2	Patellar tendinopathy
KTH	Infrapatellar fat pad syndrome (Hoffa's)
KTJ	Sindig-Larsen-Johannsen syndrome
KT4	Osgood-Schlatter syndrome
KTT	Tibial tuberosity pathology
KT5	Popliteus tendinitis/strain
KT7	Quadriceps tendinitis or suprapatellar bursitis
KR1	Ruptured patellar tendon
KH2	Infrapatella fat pad haematoma +/- bursitis

Other knee sprains

KUM	Knee jt chronic medial instability
KUA	Knee jt chronic anterolateral instability
KU1	Knee jt chronic instability
KUP	Knee jt chronic posterior instability
KJ1	Knee jt sprain/jar
KPP	Pseudogout (chondrocalcinosis), knee
KP2	Knee jt rheumatological condition/atraumatic effusion
KP3	Knee synovial plica
KP4	Knee Joint Synovitis
KL4	Knee lateral collateral ligament str/tear/rupture
KL5	Knee posterolateral complex str/tear
KO1	Complication of knee jt surgery
KZ1	Knee pain undiagnosed
QD1	Dislocated superior tibiofibular jt
QJ1	Sprained superior tibiofibular jt
QP1	Baker's cyst (+/- rupture)

Patellofemoral joint sprains

KD1	Dislocated patella
KU2	Patella instability
KP1	Patellofemoral jt pain
KB1	Bipartite patella

Patella stress fractures

KS1	Stress # patella

Knee and patella fractures

KF1	# patella
KF2	Knee # intraarticular

Knee haematomas

KT6	Prepatellar bursitis
KH1	Knee haematoma (extraarticular)
KK1	Lacerated knee
KZ2	Knee jt haemarthrosis caused by internal derangement

Leg fractures

QFS	Spiral fractured tibia + fibula
QFT	Transerve fractured tibia
QFC	Compound fracture tibia
QF1	Fracture tibia +/- fibula
QFD	Fractured distal fibula
QFH	Fractured upper fibula
QFM	Fractured mid fibula
QF2	Fracture fibula
AFB	Bimalleolus fracture
AFX	Trimalleolus fracture
AFM	Medial malleolus fracture
AFL	Lateral malleolus fracture
AF1	Pott's fracture

Leg stress fractures

QSA	Stress fracture anterior cortex tibia
QSP	Stress fracture posteromedial tibia
QS1	Stress fracture tibia
QSM	Stress fracture medial malleolus
QSL	Stress fracture lateral malleolus
QS2	Stress fracture fibula

Calf strains

QML	Lateral gastrocnemius strain
QM1	Calf muscle strain
QMS	Soleus muscle strain
QMM	Medial gastrocnemius strain
QM2	Shin extensor muscle strain
QB1	Accesory soleus muscle
QY1	Calf muscle cramps/ spasm/trigger pts
QYL	Lateral gastrocnemius trigger point
QYM	Medial gastrocnemius trigger point
QYS	Soleus trigger point
QY3	Lower leg delayed onset muscle soreness

Leg and foot soft tissue trauma

QH1	Bruised shin
QH2	Calf haematoma
QK1	Lacerated shin
QK2	Lacerated calf
QI1	Lower leg soft tissue infection
AH1	Ankle haematoma
AK1	Ankle laceration
FH1	Foot haematoma
FH2	Toenail problem/haematoma
FH3	Heel fat pad bruise
FK1	Foot laceration
FK2	Foot blistering/callus/ulcer

Shin soreness

QYB	Acute anterior compartment syndrome
QY2	Compartment syndrome
QYA	Anterior compartment syndrome
QYP	Posterior compartment syndrome
QT1	Medial Tibial Stress Syndrome ('shin splints')
QTA	Anterior shin splints

Achilles tendon

AT1	Achilles tendinopathy/ retrocalcaneal bursitis
AT2	Sever's disease
AR1	Achilles tendon rupture
ARM	Midsubstance rupture, achilles tendon
ARI	Insertional rupture, achilles tendon

Ankle sprains and joint injuries

AD1	Dislocated ankle
AUL	Lateral ankle instability
AUM	Medial ankle instability
AU1	Ankle instability
ACP	Tibial plafond chondral lesion
AC1	Ankle osteochondral lesion (inl. talar dome) +/- loose body
ACD	Talar dome chondral lesion
ACL	Loose bodies ankle joint
AJ1	Ankle jarring or joint capsule sprain
AJ2	Inferior tibiofibular syndesmosis sprain
AP1	Ankle jt synovitis (including meniscoid lesion)
AP3	Sinus tarsi syndrome (subtalar jt synovitis)
AA1	Ankle jt degenerative arthritis
ALT	Ankle lateral sprain, grade 3
AL1	Sprain lateral collateral ligament ankle
AL2	Sprain medial collateral (deltoid) ligament ankle
AT4	Ankle anterior impingement +/- osteophytes
AI1	Ankle infection
AZ1	Ankle pain undiagnosed

Foot bone fractures

AFT	Fractured body of talus
AF2	# talus or # calcaneus
AFC	Fractured calcaneus
AG1	Chip/avulsion # ankle
AGL	Fractured lateral process talus
AGO	Fractured os trigonum or posterior process
FF1	# tarsal bone (other than talus or calcaneus)
FFC	Cunieform acute fracture
FFN	Navicular acute fracture
FFB	Cuboid acute fracture
FFX	Multiple metatarsal fractures
FFS	Second metatarsal acute fracture
FFD	Fourth metatarsal acute fracture
FFF	Fifth metatarsal acute Jones fracture
FFO	First metatarsal acute fracture
FFT	Third metatarsal acute fracture
FF2	# metatarsal(s)
FF3	# phalanx (foot)
FG1	Foot avulsion #
FGF	Fifth metatarsal avulsion fracture

Foot stress fractures

AS1	Stress # Calcaneus or Talus
ASC	Stress fracture calcaneus
AST	Stress fracture talus
FSN	Navicular stress fracture
FS1	Stress # midtarsal bone (navicular, cunieforms, cuboid)
FSB	Cuboid stress fracture
FSC	Cunieform stress fracture
FST	Third metatarsal stress fracture
FSS	Second metatarsal stress fracture
FS2	Stress # metatarsal
FSD	Fourth metatarsal stress fracture
FSF	Fifth metatarsal stress fracture
FSO	First metatarsal stress fracture
FS3	Sesamoid stress fracture
FQ1	Non- or mal-union foot fracture

Foot and ankle neurovascular

QN1	Common peroneal nerve palsy (foot drop)
QV1	Deep venous thrombosis
QV2	Calf/ankle oedema
QV3	Varicose veins
QV4	Popliteal artery entrapment or arterial insufficiency
AP2	Ankle Reflex Sympathetic Dystrophy
AN1	Tarsal tunnel syndrome
AN2	Medial calcaneal nerve entrapment
FP5	Foot Reflex Sympathetic Dystrophy
FN1	Morton's neuroma or Joplin's neuritis

Other shin and foot stress injuries

QZ1	Lower leg pain undiagnosed
AT3	Ankle posterior impingement (including Os Trigonum)
AT5	Ankle extensor tendinitis (incl. Tibialis Anterior)
AT6	Peroneal tendinitis or subluxation or dislocation
AT7	Tibialis posterior or flexor hallucis tendinitis (ankle)
FC1	Foot osteochondrosis (including Kohler's and Frieberg's)
FPL	Ruptured volar plate first MTP joint
FP1	Sesamoiditis/1st metatarsophalangeal jt pain
FP3	Metatarsalgia
FM1	Foot muscle strain
FY1	Foot muscle spasm/cramps/ trigger pts
FT1	Plantar fasciitis/strain/calcaneal spur
FTD	Distal plantar fasciitis
FT2	Foot extensor tendinitis
FT6	Cuboid syndrome or foot peroneal tendinitis
FT7	Tibialis posterior insertion tendinitis

FRP	Ruptured peroneal tendon
FR1	Ruptured tibialis posterior tendon
FBT	Talocalcaneal coalition
FB1	Tarsal coalition
FBC	Calcaneonavicular coalition
FB2	Symptomatic accessory bone of foot
FB3	Foot deformity (including claw, hammer toes, bunions)
XB2	Leg length discrepency

Foot sprains

FD1	Dislocated toe
FDL	Lisfranc fracture dislocation
FD2	Dislocated joint(s) of foot (incl. Lisfranc injury)
FJ1	Sprain foot joint
FJ2	Sprained toe/'turf toe'
FP2	Tarsal joint pain/synovitis
FA1	1st Metatarsophalangeal jt degenerative arthritis
FA2	Other foot jt degenerative arthritis
FLL	Interphalangeal ligament disruption
FL1	Foot ligament sprain (including 'spring' ligament)
FZ1	Foot pain undiagnosed

Illness

HZ1	Headache/pain undiagnosed
SE1	Tumour, shoulder region
EI1	Elbow infection
PK3	Hand wart or other skin lesion
DE1	Tumour, thoracic spine
LE1	Tumour, lumbar spine
BI1	Ischial abscess
GI1	Groin rash/fungal infection
TE1	Tumour, thigh region
KI1	Infected knee jt
KE1	Tumour, knee region
QE1	Tumour, lower leg
AE1	Osteoid osteoma (ankle)
FP4	Gout (foot)
FK3	Plantar wart
FI1	Athlete's foot/tinea
FI2	Foot cellulitis/infected ulcer
FE1	Osteoid osteoma (foot)
XU1	Generalised joint hypermobility
XP1	Widespread rheumatological joint condition
XY1	Fibromyalgia/multiple trigger points
XY2	Generalised muscle spasticity/joint hypomobility
XK1	Rash or other dermatological condition
XB1	Congenital disease affecting musculoskeletal system
MI1	Otorespiratory infection (incl. tonsillitis, otitis media)
MI2	Gastrointestinal infection (including food poisoning)
MI4	Systemic non-specific virus
MI5	Virus proven by serology (e.g. Epstein-Barr, Hepatitis B)
MI6	Genitourinary infection
MI8	Infection, other
ME1	Non-musculoskeletal tumour (e.g. lymphoma)
MO1	Appendicitis
MO2	Urological including haematuria, varicocoele
MO3	Dental, eye, ear, nose or throat disease
MO8	Other surgical diagnosis
MN1	Neurological including epilepsy, migraine, coma
MV1	Cardiovascular
MX1	Environmental (incl. hyper-/hypo-thermia, barotrauma)
MX2	Condition due to drug use, overdose, poisoning
MX3	Asthma/allergy/hay fever/respiratory
MX5	Gynaecological
MX6	Psychological/psychiatric
MX7	Nutritional or haematological or enterological or endocrine
MX8	Other medical diagnosis
MZ1	Tired athlete undiagnosed
MZC	Chronic fatigue syndrome
MZ2	Other medical symptoms or signs, non-specific

Appendix G

STROBE Statement—Checklist

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarise follow-up time (eg, average and total amount)
Outcome data	15*	Report numbers of outcome events or summary measures over time
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized

		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Appendix H

Risk factors for neck injury in Rugby Union: A prospective cohort study.

Supplementary material

The largest proportion of players in this cohort had played between 10-14 years with an even distribution above and below this. The ethnic origin of those who responded in this cohort was 84% ‘anglo-Australian’ background. White collar occupations accounted for 77.1% of the participants, while 19.4% reported being blue collar workers. Alcohol consumption ranged from 0 to 50 glasses per week in this cohort (mean 12.3 drinks ± 7.9 drinks).

Table S1

Incidence and severity of neck injury per previous & current season RU neck injury

	Previous season RU neck injury		**Current preseason RU neck injury**	
Severity	**No** **Exposure** **16 824** **player-hours**	**Yes** **Exposure** **11 070** **player-hours**	**No** **Exposure** **23 163** **player-hours**	**Yes** **Exposure** **4 599** **player-hour**
Minor	(22) 1.31 (CI: 0.82, 1.98) 73.3%	(21) 1.90 (CI: 1.14, 2.90) 65.6%	(36) 1.55 (CI: 1.09, 2.15) 73.5%	(9) 1.96 (CI: 0.89, 3.71) 69.2%
Mild	(4) 0.24 (CI: 0.06, 0.61) 13.3%	(8) 0.72 (CI: 0.31, 1.42) 25.0%	(9) 0.39 (CI: 0.18, 0.74) 18.4%	(3) 0.65 (0.13, 1.91) 23.1%
Moderate	(2) 0.12 (CI: 0.01, 0.43) 6.7%	(2) 0.18 (CI: 0.02, 0.65) 6.3%	(3) 0.13 (CI: 0.03, 0.39) 6.1%	(1) 0.22 (CI: 0.01, 1.21) 7.7%
Severe	(0) 0.00 0.0%	(1) 0.09 (CI: 0.00, 0.50) 3.1%	(1) 0.04 (CI: 0.00, 0.24) 2.0%	(0) 0.00 0.0%
All	(30) *2 1.78 (CI: 1.24, 2.57) 48.4%	(32) 2.89 (CI: 2.04, 4.12) 51.6%	(49) 2.12 (CI: 1.59, 2.82) 79.0%	(13) 2.83 (CI: 1.62, 4.92 21.0%

Count (n)
Incidence /1000 player-hours (95% CIs)
Percent %
* unknown count
* 28 injuries without previous or current neck injury due to rugby status reported

Table S2
Incidence & severity of neck injury as per player's age group

Severity	18-20 years Exposure 7 500 player-hours	21-24 years Exposure 12 028 player-hours	25-28 years Exposure 7 873 player-hours	29-34 years Exposure 1 389 player-hours	35+ years Exposure 1 942 player-hours
Minor	(10) 1.33 (CI: 0.64, 2.45) 71.4%	(28) 2.33 (CI: 1.55, 3.36) 77.8%	(14) 1.79 (CI: 0.97, 2.98) 63.6%	(6) 4.32 (CI: 1.58, 9.40) 60.0%	(2) 1.03 (CI: 0.12, 3.72) 40.0%
Mild	(2) 0.27 (CI: 0.03, 0.96) 14.3%	(4) 0.33 (CI: 0.09, 0.85) 11.1%	(5) 0.64 (CI: 0.21, 1.48) 22.7%	(3) 2.16 (CI: 0.45, 6.31) 30.0%	(1) 0.51 (CI: 0.01, 2.87) 20.0%
Moderate	(1) 0.13 (CI: 0.00, 0.74) 7.1%	(2) 0.17 (CI: 0.02, 0.60) 5.6%	(3) 0.39 (CI: 0.08, 1.11) 13.6%	(0) 0.00 0.0%	(0) 0.00 0.0%
Severe	(1) 0.13 (CI: 0.00, 0.74) 7.1%	(2) 0.17 (CI: 0.02, 0.60) 5.6%	(0) 0.00 0.0%	(1) 0.72 (CI: 0.02, 4.01) 10.0%	(2) 1.03 (CI: 0.12, 3.72) 40.0%
All	(14, *1) 2.00 (CI: 1.19, 3.35) 16.9%	(36, *1) 3.08 (CI: 2.22, 4.27) 41.6%	(22) 2.79 (CI: 1.82, 4.28) 24.7%	(10) 7.20 (CI: 3.83, 13.55) 11.2%	(5) 2.57 (CI: 1.05, 6.29) 5.6%

Count (n)
Incidence /1000 player-hours (95% CIs)
Percent %
* Unknown count

Table S3

Incidence & severity of neck injury as per perceived stage of career

Severity	**Pre-peak** **Exposure** **17 509** **player-hours**	**Peak** **Exposure** **3 832** **player-hours**	**Post-peak** **Exposure** **6 337** **player-hours**
Minor	(23) 1.31 (CI: 0.83, 1.97) 71.9%	(12) 0.69 (CI: 0.35, 1.20) 80.0%	(10) 1.58 (CI: 0.76, 2.90) 66.7%
Mild	(6) 0.34 (CI: 0.13, 0.75) 18.8%	(3) 0.80 (CI: 0.16, 2.29) 20.0%	(3) 0.47 (CI: 0.10, 1.38) 20.0%
Moderate	(2) 0.11 (CI: 0.01, 0.41) 6.3%	(0) 0.00 0.0%	(2) 0.32 (CI: 0.04, 1.14) 13.3%
Severe	(1) 0.06 (CI: 0.00, 0.32) 3.1%	(0) 0.00 0.0%	(0) 0.00 0.0%
All	(32) 1.83 (CI:1.28, 2.60) 51.6%	(15) 3.91 (2.34, 6.56) 24.2%	(15) 2.37 (CI: 1.41, 3.97) 24.2%

Count (n)
Incidence /1000 player-hours (95% CIs)
Percent %
* 28 injuries without stage reported

Table S4. Incidence & severity of neck injury as a factor of ethnic origin

Severity	Anglo-Australian exposure 18 926 player-hours	Other exposure 6 941 player-hours
Minor	(28) 1.48 (CI: 0.98, 2.14) 71.8%	(9) 1.30 (CI: 0.59, 2.46) 60.0%
Mild	(7) 0.37 (CI: 0.15, 0.76) 17.9%	(5) 0.72 (CI: 0.23, 1.68) 33.3%
Moderate	(3) 0.16 (0.03, 0.46) 2.6%	(1) 0.14 (CI: 0.00, 0.80) 6.7%
Severe	(1) 0.05 (CI: 0.00, 0.29) 2.6%	(0) 0.00 0.0%
ALL	(39) 2.06 (CI: 1.50, 2.84) 72.2%	(15) 2.16 (CI: 1.29, 3.62) 27.8%

Count (N)
Incidence /1000 player-hours (95% confidence intervals)
Percent %
* 36 injuries without origin reported

Table S5. Incidence & severity of neck injury as a factor of occupation type

Severity	Blue Collar exposure 5 696 player-hours	White Collar exposure 21 013 player-hours
Minor	(10) 1.76 (CI: 0.84, 3.23) 76.9%	(33) 1.57 (CI: 1.08, 2.21) 71.7%
Mild	(2) 0.35 (CI: 0.04, 1.27) 15.4%	(9) 0.43 (CI: 0.20, 0.81) 19.6%
Moderate	(0) 0.00 0.0%	(4) 0.19 (CI: 0.05, 0.49) 8.7%
Severe	(1) 0.18 (CI: 0.00, 0.98) 7.7%	(0) 0.00 0.0%
ALL	(13) 2.28 (CI: 1.13, 3.97) 22.0%	(46) 2.19 (CI: 1.63, 2.94) 78.0%

Count (N)
Incidence /1000 player-hours (95% confidence intervals)
Percent %
* 31 injuries without an occupation reported

Table S6. Incidence of neck injury as a factor of alcohol consumption

Alcohol Consumption (glasses /week)	Count	Percent	Exposure (player hours)	Incidence /1000 player-hours	95% CI
0	(2)	3.6%	1 058	1.89	(0.47, 7.56)
1 – 4	(9)	15.5%	4 257	2.11	(1.10, 4.06)
5 – 9	(3)	5.2%	4 550	0.66	(0.21, 2.04)
10 – 14	(16)	27.6%	7 265	2.20	(1.35, 3.60)
15 – 19	(11)	19%	3 135	3.51	(1.94, 6.34)
20 – 29	(13)	22.4%	4 407	2.95	(1.71, 5.08)
30+	(4)	6.9%	1 827	2.19	(0.82, 5.83)
Total	(58*)				

*32 injuries without alcohol consumption reported

Table S7. Incidence & severity of neck injury as a factor of preparation time

Severity	000-049 Hours exposure 13 082 player-hours	050-099 Hours exposure 6 905 player-hours	100-149 Hours exposure 2 982 player-hours	150+ Hours exposure 4 092 player-hours
Minor	(22) 1.68 (CI: 1.05, 2.55) 71.0%	(6) 0.91 (CI: 0.33, 1.98) 60.0%	(5) 1.68 (CI: 0.54, 3.91) 55.6%	(8) 0.24 (CI: 0.01, 1.36) 100.0%
Mild	(6) 0.46 (CI: 0.17, 1.00) 19.4%	(4) 0.61 (CI: 0.17, 1.55) 40.0%	(2) 0.67 (CI: 0.08, 2.42) 22.2%	(0) 0.00 0.0%
Moderate	(3) 0.23 (CI: 0.05, 0.67) 9.7%	(0) 0.00 0.0%	(1) 0.34 (CI: 0.01, 1.87) 11.1%	(0) 0.00 0.0%
Severe	(0) 0.00 0.0%	(0) 0.00 0.0%	(1) 0.34 (CI: 0.01, 1.87) 11.1%	(0) 0.00 0.0%
ALL	(31) 2.37 (CI: 1.65, 3.40) 53.5%	(10) 1.45 (CI: 0.77, 2.73) 17.2%	(9) 3.02 (CI: 1.55, 5.87) 15.2%	(8) 1.96 (CI: 0.96, 3.97) 13.8%

Count (N)
Incidence /1000 player-hours (95% confidence intervals)
Percent %
* 32 injuries without preparation time information reported

Table S9. Incidence & severity of neck injury as a factor of preparation type

Severity	No Weight Train exposure 6 295 player-hours	Weight Train exposure 19 898 player-hours
Minor	(13) 2.07 (CI: 1.10, 3.53) 76.5%	(29) 1.46 (CI: 0.98, 2.09) 72.5%
Mild	(3) 0.48 (CI: 0.10, 1.39) 17.6%	(8) 0.40 (CI: 0.17, 0.79) 20.0%
Moderate	(1) 0.16 (CI: 0.00, 0.89) 5.9%	(2) 0.10 (CI: 0.01, 0.36) 5.0%
Severe	(0) 0.00 0.0%	(1) 0.05 (CI: 0.00, 0.28) 2.5%
ALL	(17) 2.70 (CI: 1.66, 4.39) 29.8%	(40) 2.01 (CI: 1.47, 2.76) 70.2%

Count (N)
Incidence /1000 player-hours
Percent %
* 33 injuries without weight training or other preparation information reported

Table S10. Incidence of neck injury as a factor of experience (years of play)

Experience	Incidence
00-04	(13) 5.6%
05-09	(48) 20.6%
10-14	(97) 41.6%
15-19	(53) 22.8%
20+	(22) 9.4%
Total	(233 *29)

Count (N)
Percent %
* Unknown count

Appendix I

Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement checklist

Table 1 | Checklist of items to include when reporting a systematic review or meta-analysis

Section/topic	Item No	Checklist item	Reported on page No
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both	
Abstract			
Structured summary	2	Provide a structured summary including, as applicable, background, objectives, data sources, study eligibility criteria, participants, interventions, study appraisal and synthesis methods, results, limitations, conclusions and implications of key findings, systematic review registration number	
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS)	
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (such as web address), and, if available, provide registration information including registration number	
Eligibility criteria	6	Specify study characteristics (such as PICOS, length of follow-up) and report characteristics (such as years considered, language, publication status) used as criteria for eligibility, giving rationale	
Information sources	7	Describe all information sources (such as databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated	
Study selection	9	State the process for selecting studies (that is, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis)	
Data collection process	10	Describe method of data extraction from reports (such as piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators	
Data items	11	List and define all variables for which data were sought (such as PICOS, funding sources) and any assumptions and simplifications made	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis	
Summary measures	13	State the principal summary measures (such as risk ratio, difference in means).	
Synthesis of	14	Describe the methods of handling data and combining	

results		results of studies, if done, including measures of consistency (such as I^2 statistic) for each meta-analysis
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (such as publication bias, selective reporting within studies)
Additional analyses	16	Describe methods of additional analyses (such as sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified
Results		
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram
Study characteristics	18	For each study, present characteristics for which data were extracted (such as study size, PICOS, follow-up period) and provide the citations
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see item 12).
Results of individual studies	20	For all outcomes considered (benefits or harms), present for each study (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see item 15)
Additional analysis	23	Give results of additional analyses, if done (such as sensitivity or subgroup analyses, meta-regression) (see item 16)
Discussion		
Summary of evidence	24	Summarise the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (such as health care providers, users, and policy makers)
Limitations	25	Discuss limitations at study and outcome level (such as risk of bias), and at review level (such as incomplete retrieval of identified research, reporting bias)
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research
Funding		
Funding	27	Describe sources of funding for the systematic review and other support (such as supply of data) and role of funders for the systematic review