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A Review of Sports Injury Data Collection Literature and Recommendations for Future Research

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ABSTRACT

Purpose: There is significant cost associated with sports injury. Establishing injury profiles in contact sports like Australian Rules Football (ARF) will facilitate implementation of injury prevention strategies. The purpose of this literature review was to investigate sports injury data collection methodology, assess the strengths and limitations of previous research and identify gaps in the relevant literature. Recommendations for methodology of future sports injury data collection studies are made, particularly with reference to junior ARF. **Method:** A non-systematic literature search was undertaken in a narrative fashion to determine past and current injury surveillance in Australian Rules Football (ARF), Soccer, Rugby league and Union. The comprehensive search was performed using databases Cinahl, Sport Discus, Medline, Science Direct, Scopus and Informit Health Database: Ausport. For inclusion in this review, studies had to include the collection of baseline data, be peer-reviewed and have full text versions available in English. The effect of the methodology on research outcomes was evaluated, including: epidemiology, aetiology, common mechanisms and risk factors for injury are evaluated, as are the incidence, prevalence, severity and pathologies of injury in relevant sports. **Results:** While other alternatives are presented and evaluated, the following criteria appear the most reliable for use in future studies. A narrow games/time lost injury definition; a similar narrow injury severity definition; and a prospective model for sports injury data collection, making use of a standardised Player Movement Record (PMR). The AFL is the only major sport in which an injury surveillance system has been created that is robust, reliable and has captured all data from all clubs over a 12 year period. This system uses all criteria outlined. **Conclusions/Recommendations:** A significant knowledge gap remains with respect to the analytical epidemiology of injuries at the non-elite level of participation and a very small evidence base exists for injury prevention in Australian football, especially at non-elite and junior levels. By using critically developed methodology in the form of a prospective cohort study, an updated sports injury data collection model, adequate sample size and consistent injury definition, future research will guide future injury prevention interventions in junior ARF.

1.1. INTRODUCTION

There is significant medical and economic cost associated with sports injury affecting athletes, teams and society.[1-5] Injury prevention strategies seem warranted in contact sports such as Australian Rules Football (ARF), however, before any injury prevention package can be implemented, the injury profile must be established.[6-8] There is little research investigating injury prevention strategies in junior ARF and it appears injury prevention research has not yet translated into coaching practices.[9,10] Scase et al (2006) demonstrated a significant reduction in injury incidence following implementation of an injury prevention program.[11] This study demonstrates the potential benefits of, and provides further justification for continued injury prevention research in addition to the improved conversion of injury prevention knowledge into practice.[11]

ARF is a full contact, dynamic sport involving explosive running, change of direction, jumping, stopping, aggressive tackling, sudden and severe collisions as well as kicking and handballing.[12] Several locomotion skills required by ARF players are also required by players in similar sports such as Soccer, Rugby League and Rugby Union.[2,13-15] Injury records for these similar sports report high levels of injury resulting from both non-contact and contact mechanisms at the senior level.[5,14,15] Injury surveillance of senior ARF from 1992 has provided information to medical officers and coaches for reviewing injury prevention programs, playing conditions, rule changes and other features of the sport. No such information is available for the sub-elite and junior competitions. Availability of such data for Under 18 level athletes would potentially provide valuable information for the same use as that for the senior levels of the sport. Future research should aim to provide injury data from an injury surveillance system established to mirror that of the AFL Injury Surveillance System for junior ARF players in the elite South Australian Under 18 competition.

A literature search was undertaken in a narrative fashion to determine past and current injury surveillance in ARF, Soccer, Rugby league and Union. Although many sports may have common injury mechanisms,[3] it is beyond the scope of this review to consider all sports. This review analyses injury definitions used in different sports, compares study designs and identifies gaps in the literature. The study design of the senior Australian Football League (AFL) injury survey is critically analysed and use of a similar system presented for future junior ARF research. The epidemiology, aetiology, common mechanisms and risk factors for injury are evaluated, as are the incidence, prevalence, severity and pathologies of injury in relevant sports.

1.2. LITERATURE SEARCH STRATEGY

A comprehensive but non-systematic review of the literature was performed using databases Cinahl, Sport Discus, Medline, Science Direct, Scopus and Informit Health Database: Ausport. For inclusion in this review, studies had to include the collection of baseline data. The search terms used were broken into five categories:

1) Australian Rules Football, Soccer, Rugby, Football, Contact sport(s), Team sport(s), Ball sport(s)
2) Injury, sport injury, injuries
3) Incidence, prevalence, severity, epidemiology, (a)etiology, mechanism(s), pathology
4) Adolescent, high school student, teenage, child
5) Data collection, injury surveillance system

Different combinations of these terms were used in different search engines to narrow or broaden the search as there were significant differences in the output of different search engines with the same search term combination. It was necessary for trial and error with these combinations to produce a reasonable output. A search revealing fewer than ten hits was considered too narrow and a search producing in excess of 200 hits was considered too broad. Boolean operators “AND” and “OR” were used with “AND” combining each number category and “OR” combining the words within each number above.

Inclusion criteria: Peer reviewed studies including the above mentioned sports (Point #1) and data collection or injury surveillance methods that were in English and had full text versions available. Descriptive cohort studies were included to consider data collection methods of different study designs. There was no limitation on the age groups as data collection methods across all ages were deemed relevant and necessary.
Exclusion criteria: Sports other than those described in Point #1 and studies without data collection or injury rate monitoring.

1.3. DEFINITIONS OF INJURY

1.3.1. Introduction

For this review it is imperative to discuss first the most important part of sports injury data collection methodology, the definition of injury. This methodological aspect influences the entire data collection process and the literature is beset with discussion of limitations in injury prevention research due to the definition of injury. This review demonstrates that a major obstacle in injury prevention research is a lack of agreement on a uniform injury definition, therefore differences in methodology have led to a lack of comparability between studies.

Definitions of injury are presented in the literature under two broad classifications, each with its strengths and weaknesses.

1. Complex definitions that attempt to capture every injury associated with the sport, whether it occurs during training or games.
2. Definitions that include only those injuries that result in a missed game or competition.

The injury definitions can influence the results regarding biases to certain types of injuries, as well as the accuracy of the outcomes by increasing or decreasing the chance of error due to increased or decreased simplicity in the definitions. There is disagreement on injury definitions even within the same sport and there appear to be reasonable arguments for and against certain definitions. The strong influences of the definitions are explained in detail in this section of the review.

1.3.2. Broad/Complex definitions of injury

1.3.2.1. Introduction

These definitions result in a bias in results towards minor injuries as every abrasion, contusion and feeling of discomfort has the potential to be recorded as an injury. Such injury types may occur multiple times every training session, and produce results highlighting game components such as tackling and bumping as mechanisms and risk factors for injury, such is the nature of these contact sports. They will increase the volume of data captured and minor injuries are less likely to be missed.

1.3.2.2. Examples from the literature

The most recent injury definitions are similar between prominent researchers in Soccer, Rugby Union and Rugby League.[14,15] These definitions are similar to:

> "Any pain or disability that occurs during participation in Rugby League match or training activities that is sustained by a player, irrespective of the need for match or training time loss or for first aid or medical attention. An injury that results in a player requiring first aid or medical attention is referred to as a 'medical attention injury' and an injury that results in the player being unable to partake in full part of future training and/or match activities is referred to a 'time loss' injury".[15, p.13]

In the study of adolescent soccer by Emery, Meeuwisse & Hartmann (2005) the definition: "any injury occurring in soccer that resulted in one or more of the following: medical attention, the inability to complete a session, or missing a subsequent session", was used.[16] Romiti, Finch & Gabbe (2008) used a definition in their research on ARF "any trauma that causes some disability or pain".[17] The study of "Injury in junior Australian Rules footballers" by Grimmer & Williams (2003) used the definition of injury "anything that significantly interferes with enjoyment of, or participation in, the sport".[9] In the early years of the AFL injury report the definition used was "injury that caused a player to miss playing time during a match or be unable to be selected in a match or participate in a training session".[18] All are examples of broad/complex definitions and each has associated strengths and weaknesses.

1.3.2.3. Strengths of complex definitions

A benefit of such definitions is that they will increase the volume of data captured and that minor injuries are less likely to be missed. A study conducted by Hodgson et al (2007) concluded that 70-92% of injuries fall into the transient category and may not cause a participant to miss competition, so the complex definitions avoid problems associated with under-reporting of injury.[19] These researchers believed that use of the encompassing complex definition enables a true global picture of injury incidence to be captured in relation to participation in any team sport.[19] Participants and those affected by the participation of competitors in these sports, including parents, will gain an insight into all possible injuries in the sport, including minor injuries such as abrasions, contusions and feelings of discomfort, any of which can lead to a lack of enjoyment. As these minor injuries are frequent in contact sports, those considering participation will be able to make their decision with the knowledge that they will most likely experience minor injuries frequently and if this is a concern they can decide not to participate.

1.3.2.4. Weaknesses of complex definitions

The chance of over-reporting injury is high, with game components such as tackling and bumping included in the resulting mechanisms and risk factors for injury (See table 5). It is highly likely that participants in these contact sports would not consider such minor injuries as significant and would be aware of their prevalence before they decided to participate. These definitions are complex and rely on accurate reporting by medical personnel to capture the large volume of injuries, a factor that could vary from club to club, thus becoming a potential limitation with a high chance of error. The requirement of more than one medical person to be involved in diagnosis and data collection is also a limitation due to different perceptions of injury and therefore the potential for inconsistent reporting. A reliance on self-reporting by participants is fraught with error due to differences in pain tolerance and opinion of what is worth reporting. The culture of these contact sports does not support self-reporting by participants of abrasions and minor injuries to coaches and medical personnel as it may affect selection and perception of a player's "toughness".[20] In fact the opposite, not reporting and therefore "playing injured", is considered a desirable trait of many contact sports.[20]

All encompassing definitions suffer serious theoretical and/or practical flaws with respect to accuracy and reliability. To date, no study using a broad definition has demonstrated good reliability (for example, using two independent recorders at the same team).[21] It is important to recognise that variations in medical support and practice and in an individual player's tolerance to pain may create differences in the incidence of injury reported. This is an acknowledged limitation of the injury definition used by FIFA, and the FIFA definitions of severity and exposure have limitations that relate to the injury definition.[14,15] Furthermore, there appears to be a lack of clarity in the definitions used by Fuller et al (2006) and King et al (2009).[14,15] It appears questionable whether in fact these definitions are all encompassing, as there is a defined term for an injury that requires "medical attention" and for one that requires "loss of time", however, while collecting "all" injuries (any pain or disability) there does not seem to be a classification for injuries that do not require attention, therefore injuries for this cohort are missed. It appears that to truly capture every minor injury, a third category of "injury not requiring attention" or something similar is required.

The definitions of injury used by Romiti, Finch & Gabbe (2008) and Grimmer & Williams (2003), said to be consistent with that of McMahon et al (1993), also have limitations due to variation in pain tolerance between participants and difficulty in recording injury in this manner.[9,17,22] Another limitation of the definitions including "missed training" is difficulty recording training attendance and reason for absence, due to communication breakdown and no efficacious training attendance recording system.[11] As a result of the high number of training sessions for contact sports and the varying reasons for absence for the large number of participants, an accurate representation of missed training due to injury appears impossible to achieve for a large cohort.

In the study involving Under 10 children by Grimmer and Williams (2003) the enjoyment of each child is likely to be highly variable and associated with different influences such as pain tolerance and parenting.[9] The injury definition used in this study is unlikely to represent an accurate injury report for the cohort, and is not appropriate to measure injuries in a cohort of an older age.[9] However, as the Grimmer and Williams' study included children who were participating in community based football clubs and "AusKick", a modified rules version of the game for younger children (http://www2.aflauskick.com.au/), the definition is far more reasonable for that age group than "games missed".[9] This definition of injury is another variation allowing for too many variables that are difficult to measure when comparing elite team sports. It does however highlight the importance of the research questions, and whether the studies using different definitions are endeavouring to answer different questions. The discussion presented in this review is based on matching the aims to the research discussed, to display an accurate representation of the injury rate for cohorts consisting of more than one team or club.

1.3.2.5 Conclusion

Research in which the broad definition is used asks the question: Although the data collection process overestimates results and is possibly inaccurate, what are all the possible injuries involved in the sport whether they are minor or major?
The large number of participants in these studies is a significant contributor to the weaknesses discussed and there is evidence to suggest complex definitions may be more suited to research involving one team within a cohort, individual sports or non-contact sports.[21] However, currently there is no research to prove this position. For a cohort consisting of a small number of participants or an individual, the high number of injuries, as a result of the complex injury definition, appears more achievable to track and record. Capturing every injury would seem desirable whether it is minor or major, however to sacrifice accuracy to achieve this is not a valid option in the context of a large cohort.

1.3.3. Narrow definitions/ Definitions that result in missed games or competition only

1.3.3.1. Introduction

Missed game/competition only definitions result in a bias towards major injuries and are likely to miss the minor injuries discussed above. Since continued participation in competition and training with minor injuries is common practice, only injuries that cause a participant to miss a game or competition are recorded. In fact, coaches encourage players to continue to participate in competition with minor injuries,[20] however, at the elite level at least, it is anticipated that such encouragement is consistent across teams so at least it is a uniform consideration. Researchers implementing this definition believe that minor injuries are normal and considered part of the game, and only injuries causing a player to miss a game are worth reporting.

1.3.3.2. Examples from the literature

Definitions similar to "injuries that result in missed games or competition only" have previously been used for research in Rugby League and the study involving junior ARF conducted by Scase et al (2006).[11] Currently narrow definitions are used for research involving International Cricket and the Australian Football League (AFL). Researchers in Rugby League have moved away from this definition due to under-reporting of minor injuries, however these researchers have failed to produce a reliable and accurate injury report since. The AFL researchers use the definition: "injury or medical condition that causes the player to miss a game".[5,21,23]

1.3.3.3. Strengths

Although the only significant sporting body to use this injury definition for a sustained period is the AFL, the AFL is also the only sporting body that has produced a reliable and accurate injury report for the last 17 years, with no missed data in the last 12 years. The AFL injury survey has resulted in significant advances in injury prevention research and will be discussed in detail later in this review.

The strength of the narrow definition is that it is simpler to use with less chance of error, thus enabling the production of a regular and accurate injury report. Such a level of accuracy is generally the aim of the stakeholders who fund injury prevention research. Orchard & Hoskins (2007) argued that a "match time loss only" injury definition is the most accurate and reliable of those commonly used in team sports.[21] A "match/time loss only" definition is the most accurate and reliable tool for comparing injury rates at different teams and between different seasons within teams. Hence, this injury definition was recommended in a consensus statement by Orchard & Hoskins (2007).[21]

The important issue of tracking player movement is also made simpler and achievable due to the narrow definition. As discussed earlier, monitoring training attendance in large cohorts is susceptible to a high chance of error, whereas tracking games is achievable, and in these high risk contact sports, missing a game is significant whereas missing training is common and accepted as part of the game.[5,21]

1.3.3.4. Weaknesses

The limitation of a missed match only definition is that its use results in a tendency to miss minor injuries and may result in a bias towards major injuries.[19] This limitation creates the potential to produce injury reports that do not necessarily reflect the frequency of injuries in the sport. Hodgson et al (2007) suggested that the majority of injuries are missed when using the narrow definition, thus creating a false impression in relation to safety.[19] Equally, as injury management improves, injuries that previously would have resulted in missed game time may now recover in time for the next match. The match time loss only definition does not allow for capture of that cohort and reflection of improvement in injury management over time.

Orchard & Hoskins (2007) acknowledged that a "match time loss only" injury definition can be reliably and accurately applied but only captures a small percentage of the total pool of all "tissue damage" injuries.[21] There are also some further inherent biases in using a match time loss only definition (late season matches, matches with unequal breaks between games), but these are clearly visible and also acknowledged by prominent researchers implementing this definition.[21]

1.3.3.5. Conclusion

The question the match loss only definition best answers is: With a high level of accuracy, what is the injury rate for a cohort, for injuries significant enough to cause a player to miss a game?
Strengthening the case to use the narrow definition is the debate considering strengths and weaknesses of both definitions presented by Orchard & Hoskins (2007) who acknowledged the limitations in detail while producing a case for their own proposed definition.[21] Prominent researchers using the broader definition have not yet produced a strong counter argument to negate the associated weaknesses. However, the arguments presented by Orchard and Hoskins (2007) must be viewed with some caution, since Orchard is the primary author of the AFL injury report and therefore, potentially has a vested interest in advocacy of the narrow definition. There appear to be no advocates for the narrow definition away from the AFL research group.

1.3.4. Injury definition recommended for use in future junior ARF studies

Throughout the literature there is a call for congruent research designs at least within the same sport to allow comparison between studies. Injury prevention researchers have experienced difficulty in this area, highlighted in a relevant systematic review by Louw, Maniiall & Grimmer (2008), where six out of the 19 papers included had a different definition of injury.[24] Significant research papers have been written for the sole purpose of obtaining a consensus on injury definition, emphasising the need for uniformity in injury prevention research.[19,21]

1.4. DEFINITION OF INJURY SEVERITY

1.4.1. Introduction

Another important component of the methodology in sports injury data collection that is closely related and dependent upon the injury definition is the definition used for injury severity. Severity of sports injuries can be described on the basis of six criteria: the nature of the sports injury; the duration and nature of treatment; sporting time lost; working time lost; permanent damage; and cost.[8]

1.4.2. Examples and the associated strengths and weaknesses

According to FIFA the average and median severity of injuries should be reported in days together with the distribution of injuries grouped according to their severity: slight (0 days); minimal(1–3 days); mild (4–7 days); moderate (8–28 days); severe(28 days); career ending.[14] In the systematic review of injury data collection by Abernethy & Bleakey (2007) injury severity was defined as time missed from sport participation, training or match because of injury.[1] Injury severity was identified by the action of players and advice offered to the players immediately after the injury in an ARF study by Romiti, Finch and Gabbe (2008).[17] The severity measures were the player: leaving the field, staying off the field, being advised to seek off-field medical advice, and being taken to hospital. The AFL researchers defined injury severity as games missed due to injury.

The definitions for injury severity found in the literature were predominantly based on time missed from participation, a strength of the "time missed" component of the definitions. As was the case for the definitions of injury, there were simple "match time loss" injury severity definitions and complex "time missed" injury severity definitions. Tracking the simple severity definition measured only by missed games appears achievable and has less chance of error. The complex severity definitions appear more challenging to measure due to difficulties in recording training attendance, resulting in a high chance of error whilst producing a detailed report. The simpler injury severity definitions may be less detailed in their outcomes, however, appear to have the ability to produce accurate reports on injury severity. The detail required in an injury report is debatable. The injury severity definition used by Romiti, Finch and Gabbe (2008), based on player reaction and advice,[17] appears limited due to difficulty in measuring player reaction as well as differences in opinion regarding advice offered to players post injury. The varying level of pain tolerance among individuals is also a limitation of the severity definition applied by Romiti, Finch and Gabbe (2008), ultimately leading to different injury severity reports for congruent injuries.

1.5. MEASURES OF INJURY INCIDENCE

According to Van Mechelen, Hlobil and Kemper (1992),[7] incidence of injury should be expressed in a standardised form of injury rate per 1000 hours of sports participation in order to facilitate the comparability of research results. However, the appropriateness of this reporting method depends upon the definition of injury used in the study.[7] Injury incidence has also been expressed per 100 players per season, per 100 matches, per 100 practices, per 1000 athlete exposures and as a percentage, as has injury prevalence, severity, mechanism and pathology.[13,15,26]

As was the case for the definitions of injury and injury severity, recommendations have been made to report injury rate in a standardised form, however, as acknowledged by Van Mechelen (1997),[27] injury rate cannot be standardised until the injury definitions themselves and the data collection process is standardised. Incidence of injury was again recorded as the number of injuries per 1000 player-hours of match exposure by Brooks et al (2005) a&b, Romiti, Finch & Gabbe (2008) and Grimmer & Williams (2003) along with numerous other studies (See Table 1).[9,17,28] The AFL researchers have previously reported injury incidence per 10,000 player-hours and per 10,000 player-weeks, however, currently the AFL researchers report injury incidence as a number and percentage of new injuries per club per season.[18,25] This change appeared to eliminate the inaccuracy associated with the estimation of time commitment required by players.

For both the "per 1000 player hours" and the "per 100 practices" measures of injury incidence, once again, the limitations are related to the inability to accurately record training attendance. Researchers measuring injury incidence in this way appear to make the assumption that all participants attend every training session and match, which is unlikely. Alternatively, these researchers attempt to record training session attendance which has previously been described as difficult. The reporting measures "per 100 players" and "number of new injuries per club per competition" appear uncomplicated to apply, aided by the use of a "Player Movement Record", a tool developed for use in Soccer studies by Junge et al (2002),[29] shown to accurately record match participation.[5,11]

1.6. SPORTS INJURY DATA COLLECTION METHODS

1.6.1. Introduction

The majority of sports injury data collection research has been observational and longitudinal in the form of prospective cohort studies, some also used retrospective and cross sectional study designs. All different study designs are reviewed in this section. In a recent systematic review of injury prevention in adolescent sport,[1] inclusion criteria incorporated intervention studies and cohort studies. These authors developed a scoring system to rate the studies with twelve meeting their inclusion criteria. Definitions varied across the studies and methods lacked consistency.[1] McGuine (2006) reported similar observations in another relevant systematic review.[4] The relevance of this significant point is that outcomes related to injury prevention research have been limited as a result of variations in methodology.

1.6.2. Retrospective Cohort Study designs

A retrospective study is a longitudinal study that looks back in time. For instance a researcher may review the injury records of previous years to look for a trend. All the events - exposure, latent period, and subsequent development of injury have already occurred.[30] The researchers merely collect the data in the present, and establish the risk of developing an injury if exposed to a particular risk factor.[30] As this study type is completed in retrospect there is no requirement for pre-study planning and organisation to collect the data in the prospective manner – which is the time consuming and therefore, costly aspect of a prospective study. Studies using questionnaires and a retrospective design have experienced limitations regarding memory errors and accuracy of surveys when measuring injury incidence.[31,32] Due to the serious errors associated with this method, the preferred option for injury rate monitoring has been a prospective design.

1.6.3. Cross sectional Study designs

Cross-sectional studies provide a "snapshot" of the frequency and characteristics of a type of injury in a population at a particular point in time. This type of data can be used to assess the prevalence of acute or chronic conditions in a population.[30] However, since exposure and injury status are measured at the same point in time, it may not be possible for causal inferences to be made.

1.6.4. Prospective Cohort Study designs

In sports injury data collection, a cohort study is often undertaken to obtain evidence in an attempt to refute the existence of a suspected association between cause and effect; failure to refute a hypothesis strengthens confidence in it. Crucially, the cohort is identified before the appearance of the injury under investigation. The pre-defined study groups are observed over a period of time to determine the frequency of new incidence of the injury under investigation. The cohort cannot therefore be defined as a group of people who already have the injury. Prospective (longitudinal) cohort studies between exposure and injury strongly aid in studying causal associations, though distinguishing true causality usually requires corroboration from further experimental trials. Certainly, co-occurrence can be identified and must be distinguished from cause and effect.[33]

1.6.4.1. Examples

Table 1 below summarizes the data collection methods of significant sporting organisations in both junior and senior ARF, Soccer, Rugby League and Rugby Union. The majority of these studies used the prospective cohort study design. Differences can be seen in the method of reporting injury rate and the injury definition.

1.6.4.2. Strengths

When considering the appropriate study design for sports injury data collection the advantage of prospective cohort study data appears to be the longitudinal observation of the group through time, and the collection of data at regular intervals, so recall error is reduced. In 2003 Bahr & Holme (2003) outlined the ideal approach for injury data collection.[39] Studies on the aetiology of sports injuries need to account for the multi-factorial nature of sports injuries by including as many relevant risk factors as possible. Risk factor studies need to be designed carefully in order to minimise bias —in most cases a prospective cohort study is the appropriate model,[39] a format that minimises the occurrence of errors associated with recall.

Prospective cohort studies are often preferred by sports injury professionals as such studies allow researchers to collect baseline participant data, information for injuries and exposure as they occur, calculate the rate of injury by participants and exposures, determine injury severity through time lost from practice and competition and identify multiple risk factors that may influence rates of injury.[1,4]

1.6.4.3. Weaknesses

Large well designed prospective cohort studies can be difficult to carry out in a sport setting because they need to use strict and sound methodology following the four general criteria listed below.[4]

1. The data collection technique
2. The sample size: the sample needs to be large enough to detect an association between variables studied and injury
3. The use of optimal data analysis techniques
4. Method of data reporting (injury rates, risk ratios, 95% confidence intervals).

Further disadvantages of this study design may include costs associated with data collection and a lack of baseline comparability between groups, due to hidden factors that may vary between different groups or teams.[40] Because a prospective study is a “follow-up” study, validity of results is highly sensitive to attrition and the drop-out rate of participants.[40] It can also take extensive time to generate useful data from this type of study.

Table 1. Different reporting methods used in research involving relevant sporting cohorts.

Study	Sport involved	Injury occurrence	Method of reporting
[18]	AFL	Games & training	Injury per 10,000 player hours/ per 10,000 player weeks
[34]	Junior & senior ARF	Games & training	Injury per 1000 player hours & per 10,000 player hours
[5,23]	AFL	Games only	Number (n) of new injuries per club per season & per 1000 player hours
[11]	Junior ARF- Victorian under 18 TAC cup.	Games only	Injury per 1000 player hours
[17]	Junior ARF	Games & training	Injury per 1000 player hours
[28]	English Rugby Union	Games & training	Injury per 1000 player hours
[35]	Australian Rugby Union	Games & training	Injury per 1000 player hours
[31]	Female Rugby- USA	Games & training	Injury per 100 matches/ per 100 practices/ per 100 exposures
[32]	Junior Basketball- South Africa	Games & training	injury as % of players sustaining an injury
[14]	Soccer (FIFA)	Games & training	Injury per 1000 player hours
[36]	Rugby Union- International Rugby Board Council	Games & training	Injury per 1000 player hours
[9]	Under 7-17 junior ARF, SANFL, school or club	Games & training	Injury per 1000 player hours
[16]	Adolescent Soccer- Canada	Games & training	Injury per 1000 player hours
[15]	Rugby League- Australia, New Zealand, United Kingdom	Games & training	Injury per 1000 player hours
[37]	Rugby League- England	Games only	Injury per 1000 player hours
[38]	Soccer- England	Games & training	Injury per 1000 player hours

1.6.4.4. Comparison and limitations of models used in prospective cohort study design research

There are three main models (See Table 2) for sports injury data collection reported in the literature, each with differences related to the assessment and implementation of the intervention, however no distinct improvements regarding the collection of baseline data.

A chronological assessment of the sports injury data collection models surprisingly revealed no request for a specific injury definition, outcome measure, data collection form or player tracking system in any model. Additionally, there were no guidelines related to the qualifications required by data collection personnel. In 1997 Van Mechelen called for a "one size fits all" model for sports injury data collection and this view has been supported throughout the literature.[1,3,6,14,16,21,27] To achieve this uniformity, strict definitions need to be outlined to enable comparison of research in future sports injury prevention studies at least within the same sport. For studies involving ARF such uniformity will allow comparison with the studies of Scase et al (2006) and Orchard & Seward (2009), and keeps consistency of definition within the sport. Standardisation of definitions is ideal for comparison across data sets.[11,25] Equally, limitations of the research and research design are more clearly evident.[7,27] As a result of the multi-factorial nature of injury prevention, comparability between studies is essential. A lack of standardised methodology has led to variations in results and the need for further research in all areas of injury prevention.[1,4] As mentioned earlier, Van Mechelen (1997) called for a "one size fits all" injury surveillance system but acknowledged different sports may require slight differences in methodology.[27]

There is a need to design an improved sports injury data collection model containing the specific definitions described above. Design of such a model that can be used universally for all sports injury prevention research may be difficult but design of a more detailed and exact methodological model does appear possible, at least for different studies within the same sport. The injury prevention models mentioned above have been used with some success in relevant studies that are comparable, and appear to

have sound framework on which to build a more detailed and exact model upon which to base future injury prevention research.[9,11,14,17,23,28,36,41]

Table 2. Prospective Cohort Study design models, commonly used by sports injury researchers.[6-8]

Van Mechelen, Hlobil & Kemper's 1992 model[7]	
Van Mechelen, Hlobil & Kemper's injury prevention model consists of four stages:	
Stage 1.	Establish the extent of the problem
Stage 2.	Establish aetiology and mechanisms of injury
Stage 3.	Introduce preventative measures
Stage 4.	Assess their effectiveness by repeating stage 1
Finch's 2006 TRIPP model[6]	
The TRIPP (Translating Research into Injury Prevention Practice) model developed by Finch (2006) is a six staged framework to base injury prevention research as seen below:	
Stage 1.	Injury surveillance
Stage 2.	Establishing aetiology and mechanisms of injury
Stage 3.	Develop preventative measure
Stage 4.	Scientific evaluation/ "Ideal conditions"
Stage 5.	Describe intervention context to inform implementation strategies
Stage 6.	Evaluate effectiveness of preventative measure in implementation context
Van Tiggelen et al's (2008) model[8]	
This model of injury prevention compliments the Finch (2006) model and has seven steps:	
Step 1.	Establishing the extent of the injury problem
Step 2.	Establishing the aetiology and mechanisms of the injury
Step 3.	Proposing a preventative measure
Step 4. & 6.	Establishing the efficacy of a preventative measure. At this point if poor repeat step 3. If good proceed to steps 5
Step 5 & 6.	
	a) Establishing the efficiency of a preventative measure
	b) Assessing the compliance and risk taking behaviour for a preventative measure. If either of these are poor then repeat step 3. If good then proceed to step 7.
Step 7.	Assess assumed effectiveness of prevention by repeating step 1

1.6.5. DATA COLLECTION MODEL RECOMMENDED FOR USE IN FUTURE SPORTS INJURY RESEARCH

From this review it is clear that the prospective cohort study design is the appropriate model on which to base future sports injury research. It is also clear that specific definitions for injury, injury severity and injury rate are required within this model in addition to setting requirements for data collectors and medical personnel regarding qualifications, data collection forms and player tracking systems. The model outlined in Table 3 seeks to achieve this, and is the model recommended for use in future studies, enabling comparison within ARF between the important studies by Scase et al (2006) and Orchard & Seward (2009),[11,25] in addition to comparison to future injury prevention research in which this framework is applied. While prominent researchers are still unable to agree on the best definitions to use, at least there is agreement that the prospective cohort study is the appropriate model and that a consensus is required for the definitions relevant to sports injury data collection.

Table 3. Recommended sports injury data collection model

Step 1. Identify specific definition of injury and definitions relevant to injury prevention research such as injury rate, prevalence and severity.
Step 2. Identify specific requirements for qualifications and procedures of medical personnel responsible for data collection.
Step 3. Design a specific player tracking system and injury reporting form for use across all injury prevention research.
Step 4. Establish the extent of the injury problem with a baseline database for injury within the cohort under investigation
Step 5. Establish aetiology and mechanisms of injury.

1.7. THE AFL INJURY SURVEILLANCE SYSTEM

The AFL injury report with high levels of compliance has led both directly and indirectly to rule changes and interventions that have decreased injury rates in the AFL. The researchers employed by the AFL to produce an injury report each year use a prospective cohort study design including a match time loss only definition. The major measurement of injury in the AFL report is seasonal injury incidence measured in a unit of new injuries per club per season. Injury prevalence is the major measurement of

the amount of playing time missed measured in a unit of missed games per club per season or as a percentage of players unavailable through injury. The recurrence rate is the number of recurring injuries expressed as a percentage of new injuries. The measures are placed in tables in a readily comprehensible report for the important stakeholders.[5] This system is one of the few injury surveillance systems that is highly reliable.[21,23] The researchers defined injury severity through games missed per injury as mentioned earlier. Based on the justification provided in the previous section of this review, the model used by the AFL would seem the appropriate model on which to base future studies. The associated weaknesses of prospective cohort studies and the narrow definition of injury are acknowledged as weaknesses of this model, but as all study designs have some strengths and weaknesses, the weaknesses are considered justifiable based on the recommended aims of future research and the strengths of the model, as the strengths appear to significantly outweigh the weaknesses.

The AFL injury surveillance system has been in operation for 17 years with 100% compliance from clubs in the last 12 years. The researchers significantly improved the data collection process in the first six years by changing their injury definition from a broad definition to a narrow definition, and in recent times credit their success to use of the earlier mentioned tool, the Player Movement Record (PMR).[5,18] The PMR is a coded spreadsheet with numbers corresponding to the playing situation of every player on the complete list, whether he is playing for the club, playing elsewhere, not playing due to injury or not playing for another reason. This player tracking system was also used by Scase et al (2006) with success as it allowed the researchers to cross check the information provided to them by the clubs and ensure no data are missed.[11] A standardised injury data collection form was specifically designed for the study by Gabbe et al (2002),[41] with a similar form used by Scase et al (2006) and the AFL clubs.[5,11]

In the seventeenth and most recent AFL injury report by Orchard & Seward (2009), the lowest rate of head & neck injuries was recorded, in addition to continued low rates of knee posterior cruciate ligament (PCL) injuries.[25] There were slightly lower rates of groin injuries in 2008 compared with 2007 and slightly higher rates of shoulder injuries in 2008 compared with 2007. The most common injury in the game remained the hamstring strain, and the most severe common injury was still the knee anterior cruciate ligament (ACL) tear, with similar rates in 2008 to 2007. There was an ongoing trend for teams to be more conservative with injury, leading to greater severity (missed playing time) per injury but lower recurrence rates.[25]

1.8. EPIDEMIOLOGY OF INJURY IN SENIOR AND JUNIOR ARF

Comparison of junior and senior injury epidemiology was difficult in this review due to a paucity of efficacious results, methodological errors and the limited number of junior ARF studies. Generally, a high incidence of lower limb injury was reported across the literature for both junior and senior ARF. Studies involving Soccer and Rugby also reported significant injury incidence, however this is not covered in detail in this review. In Appendix 1, the influence of the injury definition on epidemiological outcomes can be clearly seen. The significant difference in injury incidence reported for studies involving the same cohort by Orchard et al (1998) and Orchard & Seward (2002),[23,34] of 65.8 injuries per 1000 player hours compared to 25.7 injuries per 1000 player hours appears entirely due to a change in injury definition, from a broad definition to a narrow definition. For reasons discussed earlier the results published by researchers applying the broad definition are limited in value. Minor injuries such as soft tissue contusions were the most common pathologies reported by researchers using broad definitions. The most common pathology reported by researchers using the narrow injury definition was a hamstring strain, an outcome that appears more significant.

1.8.1. Main mechanisms and risk factors influencing injury in ARF and similar sports

As mentioned earlier, the injury risk factors and mechanisms found most significant by researchers were largely dependent on the methodology used in recording the injuries. The level of detail of the recording forms, the breadth of the injury definition and the recording ability of the data collectors appeared to affect which risk factors were exposed by the investigation. Limitations included an inability of studies to accurately report many of these risk factors. Once again the importance of the injury definition used can be seen here with not only the frequency of reporting pathology but also identification of risk factors and mechanisms. Table 4 provides a comprehensive list of risk factors and mechanisms of injury revealed in the relevant research with varying definitions.

Romiti,Finch & Gabbe (2008) and Grimmer & Williams (2003) demonstrated similarity in the mechanism of injuries in junior and senior ARF, especially as the adolescents approach 18 years of age.[9,17] The data collection methodology reviewed earlier has revealed a considerable list of mechanisms and risk factors. Explosive movements, inappropriate warm-up, lack of conditioning, attitudes of coaches, imbalances of muscles, technique and other intrinsic or extrinsic risk factors have all been demonstrated to be mechanisms and risk factors for injury.[1,2,4,18,39]

Table 4. Intrinsic/Extrinsic risk factors for sports injury identified in all reviewed studies. From Dennis & Finch (2008)[2] p.208

Intrinsic risk factors	Extrinsic risk factors
Age	Type of sport
Gender	Level of play
Previous injury	Position played
Physical fitness/Body composition	Exposure within the sport (match and training)
Muscle strength	Preseason training
Joint range of motion	Size of area of play
Balance	Time of day when participating
Nutritional status	Weather conditions
Limb dominance	Playing surface
Athletic technique	Rules of play
Knowledge of the rules	Sports officials/umpires
Skill level	Opposition players
Motivation	Coaches
Risk taking	Sports equipment
Coping skills	Protective equipment
	Footwear

Mechanisms and risk factors for the more severe injuries were revealed no matter what the definition of injury used, as would be expected. The broad injury definitions revealed further mechanisms and risk factors that were not identified in studies applying the narrow definition. These different mechanisms and risk factors can be seen in Table 5.

Table 5. Summary of possible mechanisms/risk factors revealed by studies applying the broad injury definition used by prominent sporting bodies.[2,9,14-17]

Injury	Risk Factor/ Mechanism
Muscular ache/pain	Bump, tackle, moderate to hard training, low pain tolerance
Delayed onset muscle soreness	Moderate to vigorous exercise, weights session, moderate football training session, football game/competition, low pain tolerance
Contusion- mild	Bump/tackle/collision with player
Abrasion- not requiring stitches	Fall to ground
Minor muscle strain	Vigorous exercise, football training/game
Blisters	New shoes/boots
Tiredness	Sleep deprivation, over-training

As discussed earlier some of the risk factors displayed in Table 5 are also game-skills, such as tackling and bumping, legal within the rules of the game. As a result, many coaches ensure their players practice these skills, developing techniques enabling the players to inflict physical damage on the opposition in manner considered fair within the rules.

1.9. JUSTIFICATION FOR FUTURE JUNIOR ARF STUDIES AND CONCLUSION

Louw, Maniiall & Grimmer (2008) provided the first systematic review of adolescent sports epidemiology regarding knee injury prevalence and risk factors.[24] This review highlighted an opportunity to improve the methodology of current youth sports epidemiological investigations by placing greater focus on injury definitions, injury reporting and risk factor identification. Improved methodology appears vital, as potentially positive actions, such as the implementation of an injury prevention program, may not be proposed by injury prevention policy makers, as the true scope of the problem may be masked by methodological errors. Future research in the field of sport injury should thus ensure that valid and reliable measurements are used to collect the data.[24]

There is clearly a need to prevent lower extremity injuries in ARF and prevent them as early as possible.[5,6,9,17,42,43] In Australia, ARF is the most popular spectator sport with the highest participation rates and incidence of injury.[2,42-44] Data taken from hospital attendances cited contact sports as the highest origin of presentation, with Australian football being the largest contributor.[42] The injury toll has an effect on a player's potential career earnings, personal well being and may also impact on long term health of

retired players.[43] It appears that one of the major threats to the game is the increasing concern of parents not allowing children to participate as a result of the injury facts related to the sport. At the elite level of ARF the speed of the game has doubled over the past 40 years, as has the estimated number of collisions.[6,43] At the same time, the stakes of the game have significantly increased to the point where, in 2009, the business of ARF is the strongest it has ever been where players will go to almost any lengths to win.[5] Orchard & Seward (2008) hinted in the 2007 AFL injury report that to solve the injury problem at senior level, injury prevention needed to be addressed within junior and club programs.[5] Taking into account that junior sportspeople will mature and develop, injury prevention techniques would seem appropriate at an early age, with the potential to prevent loss of talented young players to the game through injury. As they mature and develop, through participation and knowledge gained from injury prevention programs there is the potential to optimize the conditioning of these young bodies to prepare them for the rigors of both contact and non-contact sports at a senior level, especially in brutal sports such as Australian Rules Football.

Injury surveillance is now considered a universal obligation of professional sporting bodies.[6,7,27] However, Gabbe et al (2002) studied players from Amateur ARF clubs with the results demonstrating a need to look beyond the AFL to guide injury prevention at the community and junior levels.[41] A reliance on injury data from the elite-level of Australian football may not be appropriate due to differences across the levels with respect to exposure, fitness and skill. There is a large amount of research at the senior level of the sport but few sound studies at the junior level. As a result, a significant knowledge gap remains with respect to the analytical epidemiology of injuries at the non-elite level of participation and there is a very small evidence base for prevention of injuries in Australian football.[45] By using critically developed methodology in the form of a prospective cohort study, an updated sports injury data collection model, adequate sample size and consistent injury definition, future junior ARF research will guide future injury prevention interventions.

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