PROSPECTIVE EPIDEMIOLOGICAL STUDY OF INJURIES IN THE AUSTRALIAN NATIONAL SOCCER COMPETITION

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A thesis submitted in partial fulfilment of the requirements for the degree of Masters by Research at the University of Sydney

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CANDIDATE'S CERTIFICATE

I, Peter Colagiuri, hereby declare that the work contained within this thesis is my own and has not been submitted to any other university or institution as part of a whole requirement for any higher degree.

I, Peter Colagiuri, hereby declare that I was the principal researcher of all work included in this thesis, including work published with multiple authors. A statement from co-authors confirming the authorship contribution of the Masters candidate is provided in Appendix 1.

I, Peter Colagiuri, understand that if I am awarded a higher degree for my thesis entitled "Prospective Epidemiological Study Of Injuries In The Australian National Soccer Competition" being lodged herewith for examination, the thesis will be lodged in the University Library and be available immediately for use. I agree that the University Librarian (or in the case of the department, the Head of the Department) may supply a photocopy or microform of the thesis to an individual for research or study or to a library.

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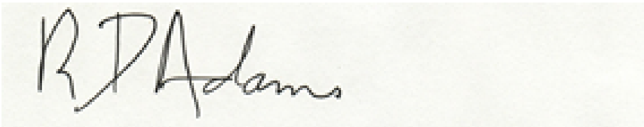

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ABBREVIATIONS

ACL	Anterior Cruciate Ligament
AFL	Australian Football League
AT	Achilles Tendon
FFA	Football Federation Australia
FIFA	Fédération Internationale de Football Association
IRB	International Rugby Board
MCL	Medial Collateral Ligament
NAIRS	National Athletic Injury Registration System
PCL	Posterior Cruciate Ligament
RR	Relative risk
TRIPP	Translating Research into Injury Prevention Practice
UEFA	Union of European Football Associations

ABSTRACT

Sporting participation has numerous benefits to the individual and the community. Sports injury is an unfortunate consequence of participation and can have a negative physical, psychosocial and financial impact. Prevention of sporting injury can reduce the barriers to sporting participation. Injury prevention methodology considers injury surveillance to be one of the initial steps in the process of planning, developing and assessing the effectiveness of any prevention strategy implemented.

Injury surveillance relies on a clear and unambiguous definition of injury and a reliable method of data collection to provide an accurate profile of injuries. Globally, there is published injury surveillance data available for professional soccer competitions in most regions of the world, with the notable exception of the Australian competition. Within Australia, injury surveillance results have been published for Rugby League, Rugby Union and Australian Rules Football.

Our injury surveillance of the Australian professional soccer competition allows comparison to global injury data on soccer injuries and to other football codes within Australia. It also quantifies the significant risk of subsequent injury after an initial hip/groin injury and the player salary cost of injury in the Hyundai A-League.

This new data advances the knowledge base of the sporting injury profile of professional soccer and informs the next stage of injury prevention program development.

An injury surveillance method involving web-based technology is presented, using currently available technology to provide easy-to-use yet comprehensive recording of injuries across all levels of sport. The potential for in-season monitoring of performance characteristics as a predictor of injury is also presented.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Background

The importance of sport in Australia has been demonstrated by the extent of Australian Government funding for sport, reaching A$1.2 billion over a four year period (Australian Government, 2010). At a societal level, enthusiasm for participation in sports can offer particular benefits. Information and understanding regarding the injuries that inevitably arise from sport participation is therefore important both from the perspective of the injured individual and for society as a whole.

Health and societal benefits of sporting participation

On an individual level, the benefits of participation in physical exercise include enhanced quality of life, improved longevity and reduced risk of disease. Improvement in quality of life is more pronounced with club sports (Eime, Harvey, Brown, & Payne, 2010) and outdoor activities (Thompson Coon et al., 2011) compared to participation in individual or indoor sports. An increase in life expectancy has been noted specifically with endurance/aerobic sports (Reimers, Knapp, & Reimers, 2012; Sarna, Sahi, Koskenvuo, & Kaprio, 1993; Teramoto & Bungum, 2010) and team sports,(Sarna & Kaprio, 1994; Sarna et al., 1993) with an even greater improvement in longevity seen in athletes at the elite level (Sarna et al., 1993; Teramoto & Bungum, 2010). There is evidence of improved cardiovascular function along with reduced rates of several major diseases such as cancer (Adami, Negro, Lala, & Martelletti, 2010; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010; Warburton, Nicol, & Bredin, 2006), stroke (Warburton et al., 2010) and diabetes ("American College of Sports Medicine Position Stand. Exercise and physical activity for older adults," 1998; Warburton et al., 2010). This is accompanied by improved cognitive function and self-efficacy ("American College of Sports Medicine Position Stand. Exercise and physical activity for older adults," 1998).

Sport plays an important role in the development during the formative years of childhood in that it leads to higher levels of self-esteem and confidence (DeMeulenaere, 2010) as well as a more positive social and academic self-concept (Blomfield & Barber, 2009) in the adolescent years. Sport also aids in the development of motor coordination skills throughout the childhood years, with participation in a broad range of sports (Fransen et al., 2012) and participation in club sports (Vandorpe et al., 2012) shown to enhance the acquisition of these skills.

The benefit of exercise is not limited to the individual but extends to society in general. The reduced rates of hospital admissions seen after only a few years of exercise (Patel et al., 2011) indicate that the reduced risk of disease closely follows the uptake of exercise. Increased participation in physical activity has the potential to markedly reduce morbidity and mortality rates as well as to deliver sizeable reductions in healthcare costs and workplace productivity (Cadilhac et al., 2011). Theoretical modelling by Cadilhac et al (2011) found that a 10% reduction in Australia's inactivity rate would lead to a A$96 million reduction in health sector costs.

Physical and psychosocial impact of injury

An almost inevitable consequence of participation in sport is musculoskeletal injury. Injury can impact on an individual's ability to continue to participate, both in the short and long term. Injury can affect physical capacity to participate in the immediate period after the injury. In the case of some injuries, and for some players, this physical limitation may be associated with psychological stress due to lack of participation. Professional players may have reduced earning potential arising from future performance limitations due to injury. Recreational athletes may suffer reduced income if the injury interferes with their workplace duties as well as incurring the cost of injury rehabilitation. Despite recovering from the physical limitations of injury, the resultant financial and lifestyle impact can reduce athletes' motivation to participate over the longer term. Issues such as depression and increased chronic disease risk may arise with a lack of participation in physical activity, amplifying the magnitude of the negative consequences of the initial injury (Ponzer, Bergman, Brismar, & Johansson, 1996).

Prevalence and cost of sporting-related injury

Musculoskeletal injury in sport is surprisingly common, with 5.2 million Australians sustaining a sports-related injury in 2005 (Medibank Private Limited, 2006) and 7 million Americans receiving medical attention for sport and recreational injuries annually (Conn, Annest, & Gilchrist, 2003). Finch and Cassell (2006) found the prevalence of injuries requiring treatment or interfering with performance or participation was 10.7% of soccer players in a community-based survey. Bollars et al (2014) noted that recreational level players suffer more injuries than elite or national level players with 7.2 injuries per 100 recreational players per season compared to 4.4 injuries per 100 national level players per season.

The direct medical costs associated with injury include diagnostic testing (eg medical imaging) and conservative and/or surgical management. The Medibank Private Safe Sports Report (2006) found that a knee injury can incur medical, surgical and rehabilitation costs averaging between A$11,000 and A$16,500 while a back injury averages up to A$22,000. In the US, there are approximately 23,000 ankle sprains each year (Kannus & Renstrom, 1991) accounting for 1.6 million doctors visits and 8,000 hospital admissions (McKeon & Mattacola, 2008).

Aside from the direct medical costs and burden on the healthcare sector, there are indirect costs to society associated with injury which include loss of productivity and absenteeism, and these can be up to four times greater than the direct costs (Hupperets et al., 2010). Injury recovery and its related expenses and lifestyle impact on the individual and can provide a subsequent disincentive to sports participation, potentially reducing participation rates over the lifespan (Maffulli, Longo, Gougoulias, Loppini, & Denaro, 2010). These reduced rates of involvement are linked to a more sedentary lifestyle, increasing the risk of major illness and the healthcare sector costs associated with their management (Maffulli, Longo, Spiezia, & Denaro, 2010). Logically therefore, the focus of the respective health professionals should be on prevention programs to minimise injury rates and reduce the long-term burden on the healthcare sector (Maffulli, Longo, Spiezia, et al., 2010). Where injuries occur as a result of professional sports participation, the relevant sporting body/club bears a significant financial burden also. The club, as an employer, is responsible for the medical costs associated with injury in addition to ongoing salary payments, despite the injured player being unavailable for selection. The indirect or hidden cost of injury can far exceed the medical and salary costs as a club may lose revenue from gate takings when a marquee player is unavailable or the team may miss a berth in the finals series due to losses attributable to key player absences. While medical and salary expenses are often in tens of thousands of dollars, a poor team performance may lead to over a million dollars in lost revenue. Logically, the focus of the respective health professionals should be on prevention programs to minimise injury rates and reduce the long-term burden on the healthcare sector (van Beijsterveldt et al., 2011).

Injury Surveillance in Sport

Surveillance as the first step in injury prevention

The ultimate goal of sports medicine research is effective injury prevention. The "Translating Research into Injury Prevention Practice" or TRIPP model proposed by Finch (2006) suggests that injury surveillance is the initial step in working towards this goal as well as a critical factor in evaluating the effectiveness of any proposed preventative intervention. The influential van Mechelen's (1997) "sequence of prevention" commences and concludes with injury surveillance, in order to establish the aetiology of injury and evaluate preventative measures that have been instigated. The TRIPP injury prevention model encourages ongoing evaluation of programs or recommendations aimed at minimising the risk of injury and can assist in identifying treatment effect size on a variety of populations.

Current surveillance-informed injury prevention measures

In 2003, an injury prevention program known as the "FIFA 11" was developed for amateur soccer players by a panel of international experts on behalf of the sport's governing body and consists of eleven exercises to be completed prior to training sessions ("The "11+" - FIFA.com,"). This program was later redesigned in 2006 and was renamed "FIFA 11+". These programs were developed by a panel of prominent researchers in the field of soccer injuries and injury prevention and tested on a variety of cohorts with mixed results. The FIFA 11 program was not found to be effective at reducing injuries for a small cohort of amateur male soccer players in 6th and 7th division Italian League teams (Gatterer, Ruedl, Faulhaber, Regele, & Burtscher, 2012). However a reduction in injuries was observed following a countrywide intervention of the FIFA 11 for amateur soccer players (Junge et al., 2011). Overall it would appear that the prevention program is likely to be effective at reducing injury rates in amateur soccer players as studies with larger sample sizes and longer time periods found favourable results (Junge et al., 2011). Interestingly, a reduction in injuries was also observed in a cohort of elite male basketball players using the FIFA 11+ (Longo et al., 2012). Studies that found no significant difference between players who performed the prevention program and those who did not may have had insufficient sample sizes and lacked statistical power (Gatterer et al., 2012).

Confirming the value of injury surveillance in informing interventions aimed at reducing risk, Gabbett (2004) investigated whether a reduction in training load during the sub-elite rugby league pre-season would affect injury rates. After conducting injury surveillance during the 2001 pre-season period, the training duration was reduced in 2002 and 2003 and the training intensity was reduced in 2003, resulting in reduced pre-season injury rates.

Injury prevention has also been achieved by altering the rules of play. Rule changes are typically proposed in response to observed injury trends associated with a specific aspect of a game. For example, in response to a high incidence of posterior cruciate ligament (PCL) injuries among ruckmen, the AFL sought to modify rules governing the part of the game with the highest incidence of the injury (Orchard & Seward, 2009). As the majority of these injuries seemed to be occurring at the centre bounce, where opposing ruckmen would collide at running speed, with tibia-to-tibia contact, the AFL's medical advisors proposed a modified distance allowable for the running approach to this contact in an attempt to reduce the force of the collision. Subsequent injury surveillance found a significant reduction in PCL injuries to ruckmen as a result of this rule change (Orchard & Seward, 2009).

Not all proposed rule changes are aimed at reducing the risk of injury however injury surveillance is vital in determining their effect on injury rates. The International Rugby

Board (IRB) experimental law variations, trialled in southern hemisphere matches with an aim of simplifying the game, failed to lower the rate of injuries incurred (Fuller, Raftery, Readhead, Targett, & Molloy, 2009). The premise of the law variations was primarily enhancing the spectator's experience by improving speed of play, and the variations did reduce the number of injuries in rucks and mauls. However the increased speed of play also led to more injuries from tackles. Ongoing injury surveillance can inform the governing body of a sport about the effects of law variations on injury rates and assist them in determining the overall result of any variations.

Finally, equipment that has been demonstrated to confer a positive/protective effect on injury rates may also be recommended or mandated based on the results of injury surveillance. This intervention has been instituted particularly in response to high frequency injuries or injuries with severe consequences. Orofacial injury can have severe consequences and mouthguards are often recommended in sports where this type of injury may occur. A systematic review of surveillance studies by Knapik et al (2007) found that the risk of orofacial injury was 1.6-1.9 times higher in those not wearing a mouthguard although there was no evidence that any sport had introduced mandatory mouthguard use as a direct result of these findings. The use of ankle braces/taping is now commonplace in sports such as netball with a significant reduction in the risk of subsequent ankle sprains in previously injured athletes, although the intervention seems ineffective in the uninjured population (Verhagen & Bay, 2010). Padded headgear, previously recommended to prevent concussion and head injury, has not been found to significantly reduce the incidence of head injuries in Rugby Union (McIntosh et al., 2009). With the aid of injury surveillance, medical professionals and governing bodies can provide evidence-based recommendations to players on protective equipment and likely effects of their use.

Efficacy of surveillance data reporting methods

Injury surveillance has been undertaken for many decades; however the utility of injury surveillance data is highly dependent on its accuracy. Several factors may affect the accuracy of collected data and therefore whether the data might be successfully used to effect a reduction in injury incidence and prevalence. The outcome of an injury study can be affected by injury definition, research design, methodology and analysis employed (van Mechelen, Hlobil, & Kemper, 1992).
The method of data collection can also affect the accuracy of the outcome. A study employing prospective recording of injuries by team medical staff, validated against an aggregate of medical centre staff reports and player recall, underestimated injury by 19% over a three month period (Bjorneboe, Florenes, Bahr, & Andersen, 2011). Recall bias has long been noted as a factor affecting accuracy of injury data collection using retrospective study design. One study found that retrospective player interviews underestimated injuries by 30% over the same period (Bjorneboe et al., 2011) with time to recall following injury negatively associated with data accuracy. Players who were asked to recall injury information from the previous four weeks demonstrated acceptable to good levels of agreement between recall and objective data on the injured region and treatment sought. However there was a low level of agreement on injury severity, even at four weeks (Valuri, Stevenson, Finch, Hamer, & Elliott, 2005). Recall accuracy was further diminished with greater detail required, such that after 12 months only 61% of players were able to recall the number, location and diagnoses of their injuries (Gabbe, Finch, Bennell, & Wajswelner, 2003).

Factors affecting injury rates

Football injury rates vary across the globe due to climatic conditions, differences in match congestion and variations in the playing surface (see Table 1). Professional soccer teams from Mediterranean climates report lower rates of overall injury, training injury and severe injury but had a higher rate of anterior cruciate ligament (ACL) injury when compared to teams from Northern European climates (Walden, Hagglund, Orchard, Kristenson, & Ekstrand, 2011). The variation in injury rates could not be attributed solely to climatic differences but may be explained by a multitude of factors, including playing style and refereeing standards (Walden et al., 2011). Incongruities in the training load between regions were adjusted for as the authors accounted for exposure rates in their injury data.

Professional competitions worldwide demand different frequencies of matches per week and playing two matches per week has been associated with an increased injury rate compared to playing one match per week (Dupont et al., 2010). A similar study found no association between match frequency and injury rates however this study only recorded injuries sustained in matches, not training, and thus may present an incomplete account of the injury profile of the team studied (Carling, Orhant, & LeGall, 2010).

Another factor that can lead to regional variations in injury rates is the playing surface (see Table 1). Early versions of artificial turf have been associated with higher rates of injury compared to natural turf (Dragoo, Braun, & Harris, 2013; Hershman et al., 2012). Later generations of artificial turf have demonstrated similar injury rates to natural turf although there are variations in reported injury type between the two surfaces (Dragoo & Braun, 2010). Within the spectrum of natural turf, perennial ryegrass has been associated with a reduced rate of ACL injuries (J. Orchard, 2002), as have regions with lower water evaporation and higher rainfall, potentially due to a greater softening of the ground (Orchard, Seward, McGivern, & Hood, 1999).

Table 1: Factors affecting injury

	Region	Injury Reported	Factor ascribed to injury	Increased risk
Orchard et al (1999)(Orchard et al., 1999)	Australia	Non-contact ACL injuries	Water evaporation	RR 2.80 with high water evaporation in the month before the injury
			Rainfall	RR 1.93 with low rainfall in the year before the match
Carling, Orhant & LeGall (2010)(Carling et al., 2010)	France and Europe	Overall injuries	Match congestion	No increased risk with less than 4 days between matches
Dragoo & Braun (2010)(Dragoo & Braun, 2010)	International	Overall injuries	New generation artificial turf	No increased risk with 3rd generation artificial grass compared to natural grass
Dupont et al (2010)(Dupont et al., 2010)	Scotland and Europe	Overall injuries	2 games/week compared to 1 game/week	25.6 compared to 4.1 injuries per 1000hr participation
Walden et al (2011)(Walden et al., 2011)	Europe	Overall injuries	Mediterranean climates	RR 1.12 in Northern European climates
		ACL injuries	Mediterranean climates	RR 0.43 in Northern European climates
Dragoo, Braun & Harris (2013)(Dragoo et al., 2013)	USA	ACL injuries	Artificial turf	RR 1.39 on artificial grass compared to natural grass
Orchard et al (2013)(J. W. Orchard et al., 2013)	Australia	Overall injury	Warmer climates	RR 1.05 in warmer climates
		ACL injuries	Warmer climates	RR 0.70 in warmer climates

(RR: Relative Risk)

Injury surveillance in other codes of football played in Australia

In Australia, injury surveillance has been undertaken in Rugby Union (McIntosh, Savage, McCrory, Frechede, & Wolfe, 2010; Usman & McIntosh, 2012), Rugby League (Gabbett, 2003, 2004) and Australian Rules Football (Orchard & Seward, 2009; J. Orchard & Seward, 2002). In Australian Rules Football, injury surveillance has been undertaken and reported on a yearly basis dating back to 1992 (J. Orchard & Seward, 2002), leading to injury prevention recommendations (Gabbett, 2004), prevention models (Gatterer et al., 2012) and rule changes (Fuller et al., 2009; Gabbett, 2005) and contributing to a reduction in specific injury rates (Orchard & Seward, 2009) (see Table 2).

It is also the role of injury surveillance to identify any changes in injury risk associated with rule changes that were implemented for non-injury related reasons (see Table 2). Relative risk of injury was reduced after the introduction of a limited interchange system in Australian Rugby League, possibly due to a fatigue-induced reduction in the speed of play and magnitude of contact forces experienced during player collisions (Gabbett, 2005). This rule was been initially introduced to improve speed of play for the benefit of spectators due to an increase in fatigue-related defensive lapses.

Table 2: Change in injury rate as a result of instituting a preventative intervention

Study	Code	Intervention	Result
Junge et al (2002)	Soccer	FIFA 11 exercise program	Reduced injury rate in low > high skill level teams
Gabbett (2004)	Rugby League	Reduced pre-season training load	Reduction in incidence of injury in pre-season
Gabbett (2005)	Rugby League	Limited interchange rule	30% reduction in injury risk
McIntosh et al (2009)	Rugby Union	Padded headgear	No reduction in head injuries or concussion
Fuller et al (2009)	Rugby Union	Experimental law variations	Higher incidence, lower severity, no effect on distribution or type of injury
Orchard & Seward (2009)	AFL	Ruck rule change	Reduction in PCL injuries
Gatterer et al (2012)	Soccer	FIFA 11+ exercise program	No effect on injury rate
Steffen et al (2013)	Soccer	FIFA 11+ exercise program	Reduced injury rates in high adherence group
Verhagen (2013)	Soccer	FIFA 11 exercise program	No effect on injury rate

Global soccer injury surveillance

Soccer-related injury surveillance studies from the UK (Hawkins & Fuller, 1999; Woods, Hawkins, Hulse, & Hodson, 2003), Europe (Hagglund, Walden, & Ekstrand, 2003, 2005; Junge, Chomiak, & Dvorak, 2000; Petersen, Thorborg, Nielsen, & Holmich, 2010; Walden, Hagglund, & Ekstrand, 2005; Walden et al., 2011), Africa (Azubuike & Okojie, 2009), USA (Agel, Evans, Dick, Putukian, & Marshall, 2007; Dick, Putukian, Agel, Evans, & Marshall, 2007) and South America (Correa et al., 2010) profile injuries at the highest level of professional soccer. Such studies have been published comparing adjacent regions of Europe where similar competitions exist with variations in season and training to game ratios (Hagglund, Walden, & Ekstrand, 2005). Hagglund et al (2005) compared Swedish and Danish professional teams where there are differences in training loads and seasonal variations. When compared to the Danish competition, the Swedish teams experienced a higher rate of training injuries coupled with greater training hours and a longer pre-season period (Hagglund, Walden, & Ekstrand, 2005). There were also seasonal variations between the competitions with the Swedish competition played from Spring to Autumn compared to Denmark's playing period of Autumn to Spring (Hagglund, Walden, & Ekstrand, 2005). The comparison of injuries from different regions illustrates the variety of rates, body location and types of injury that are based on numerous contributing factors (Hagglund, Walden, & Ekstrand, 2005; Junge et al., 2000; J. W. Orchard et al., 2013; Walden et al., 2011). Attempting to isolate the contribution of individual factors and groups of factors and adopting the most effective injury reduction strategies from any region around the world may optimise harm minimisation. These studies contribute to the collective profile of injury risk in soccer and assist in advising the international governing body to aid in the development of rule changes and prevention programs (Finch, 2006). Despite the demonstrated efficacy of soccer injury prevention programs (Junge et al., 2011), there is as yet no evidence of rule changes implemented by FIFA in response to injury surveillance (Klugl et al., 2010).

Selection of various injury definitions and their implication

The definition of injury used in injury surveillance is of vital importance as it allows or prevents comparison between studies (Hagglund, Walden, Bahr, & Ekstrand, 2005) and between injuries. To be useful, it must clearly and unambiguously define an injury and be able to quantify two different injuries on a common scale. As there are different methods of quantifying an injury, difficulties are encountered when comparing injury surveillance data with inconsistent injury definitions, even within the single sporting code (Hagglund, Walden, Bahr, et al., 2005). Typically the prevailing injury definition is selected for reasons relating to the qualifications of the data recorder and the availability of medical services. Another important factor in the selection of an injury definition is the presence of historical surveillance data from the same cohort. While it may be ideal for all injury surveillance studies to align their definitions, comparison to previous years' data is only possible by maintaining a consistent definition. For this reason we are unlikely to reach a consensus on one definition for use in injury surveillance studies across all levels of the sport.

On reviewing the literature, there appear to be four main categories of injury definition in use each with their own rationale and focus. These are tissue damage, medical attention, missed games and time-loss. A "tissue damage" definition states that a player is injured when suitably qualified medical personnel deem that they have sustained damage to the tissue (Junge, Dvorak, Graf-Baumann, & Peterson, 2004). This definition relies heavily on the availability of medical staff and has typically been used at major sporting events, such as FIFA World Cup and Olympic Games, where such staff are readily available. For most clubs, routine medical imaging is not commonplace making a “tissue damage” definition reliant upon the opinion of the clinician or player and consequentially of questionable validity. The definition does not require that a player be absent from games or training or be restricted in their function. Use of this definition will result in injuries being recorded that were not of sufficient severity to limit a player’s capacity, or injuries to body areas that may not be directly involved in the sport, such as a finger injury for a soccer player in a field position. Another limitation with this definition is the lack of coverage by suitably qualified personnel at training sessions, even at a professional level, and lack of game coverage by medical personnel at the lower tiers of most sports. Where medical services are unavailable at some training sessions, it is difficult to monitor player participation between games.

A "medical attention" injury definition states that a player is recorded as injured when they seek medical evaluation (Morgan & Oberlander, 2001). This definition does not require players to be absent from training or games or to have their performance adversely affected (Hagglund, Walden, Bahr, et al., 2005). Injury rates associated with this definition will be affected by minor complaints that do not limit a player’s ability to participate and may otherwise be classified as minor soreness. The outcome of surveillance based on this definition will also be affected by the availability of medical personnel. Where medical personnel are unavailable during training sessions, less significant injuries will not be recorded thus reducing the recorded injury rate when compared to a club with medical personnel at all training sessions.

The “games missed” definition of injury sees a player listed as injured when there is an injury-related absence from games. Requiring the least surveillance diligence, the “games missed” definition often becomes the default definition for comparison as data on missed games can be extrapolated from most injury surveillance studies.

This definition may be unambiguous and easily audited (J. Orchard & Seward, 2002) but it lacks sensitivity for injuries that only limit training performance and it will be affected by extended periods between matches due to holiday periods or bye rounds. When a player is perceived as being highly valuable to the competition, it is possible for them to miss extensive periods of training due to injury but to take the field on a weekly basis for competition. The “games missed” definition of injury would fail to identify such a player as injured at all. Where a busier match schedule existed and the player was injured for the same period of time, the mid-week game would lead to an injury being recorded, thus altering the outcome of injury surveillance. Therefore this definition would only be useful for between-study / cohort comparison where the match schedule between the observed periods was identical. The addition of Friday and/or Monday matches to the regular weekend games or the addition of a bye to the fixtures would affect the outcome and make comparison difficult.

A “time-loss” definition has been recommended by a panel of international experts convened by UEFA (Union of European Football Associations) however this definition is subject to some interpretation (Hagglund, Walden, Bahr, et al., 2005). The premise here is that a player is injured when they are unable to continue to play or train with the team. This definition should account for injuries that impact performance however interpretation is required where the player is able to participate in an easier training session or where they can fully participate in only a portion of a training session. The potential ambiguities associated with partial or limited performance can affect injury severity by altering the exact date of return from injury. It will also affect injury recurrence rates as a new episode of injury would be recorded if a player is pre-emptively declared fit after limited involvement in training only to withdraw from more intense training later in the week. The impact of an incomplete return, where a player reinjures prior to making a complete return to team participation, would produce a lower incidence but higher severity estimate for that injury. Conversely, a definition that lists a player as recovered once they participate in part of a training session may lead to a higher incidence and reduced severity, despite the player sustaining their reinjury during their return to sport testing during team training. Accordingly, care must be taken to ensure that this transition from injury to full participation is clearly defined. An example of this would be requiring that a player be declared fully fit and unrestricted by medical staff or complete a full training session or game before declaring an end to the injury episode. However where team medical staff understand and adopt it this definition offers the most valid measure of the functional impact of injury and is sensitive to changes occurring between games.

Development of a novel Injury Surveillance Reporting instrument

Any system utilised by team medical staff to record player injuries and exposure should enhance reporting accuracy by maintaining a degree of simplicity while including sufficient variables to provide worthwhile results (Gabbe et al., 2003). With this focus, we have designed an injury surveillance reporting form utilising Microsoft Excel software due to its widespread use, ease of operation and accessibility via a number of devices including computers and tablets. The form consists of one sheet per week of data, with team details including player names automatically populating the data fields for each week after the initial entry. There is a section to record team training minutes for exposure calculations, with any reduction in training time for individual players recorded with the player’s weekly data. The information required for each player included their availability for selection, thus concluding an injury episode, and their game and training involvement for exposure calculations. Further information for injured players includes whether the injury is a new injury or a recurrence, with recurrences divided into less than 12 months or greater than 12 months since the last occurrence. The venue at which the injury occurred is also recorded to determine the incidence of injury at games, training or during other activities. Specific injury data including the site, side and any relevant diagnostic imaging results are also collected as well as the expected duration of absence. The injury information has been selected to allow grouping and comparison of injury, both within the A-League and to data reported in research publications.

Requirement for injury surveillance in Australian professional soccer

There is a need for a high quality injury surveillance study in Australian professional soccer to enable comparison to other Australian football codes and well as soccer injury data from other regions around the world. Australia is in a rare situation in that it is a nation where all four football codes are played. This provides an opportunity to compare Australian soccer injury data with injury data from Australian Rules Football (J. Orchard & Seward, 2002; Seward, Orchard, Hazard, & Collinson, 1993), Rugby League (Gabbett, 2000, 2003; Seward et al., 1993) and Rugby Union (Bathgate, Best, Craig, & Jamieson, 2002; Seward et al., 1993) to identify potential factors impacting the nature of injuries related to the demands of the game as well as seasonal variations, as soccer is the only code played over a full summer season. Australia is not represented in current international soccer injury data and a research study would therefore provide an ideal data set to compare with northern hemisphere regions due to the contrast in weather conditions, ground types (J. Orchard, 2002) and playing style (Foster, 2008). In order to bring these elements together, the decision was made to conduct a full season of injury surveillance in Australian professional soccer.

Aims of the thesis

The aim of this thesis was to provide a detailed profile of injuries in Australian professional soccer as a further evidence base with which to plan and develop new prevention strategies to minimise soccer injuries in professional players.

Objectives of the thesis

To achieve these aims, the objectives of this thesis are to:

- Describe the current injury situation for recreational sport in Australia and other regions of the world
- Critically appraise the available literature to determine the most appropriate injury surveillance methodology
- Determine the current injury profile in Australian professional soccer
- Describe the current understanding of the injury situation of high level and professional soccer competitions in other regions of the world
- Compare the current injury situation in Australian professional soccer to the injury profile of high level and professional soccer in other regions of the world
- Describe global variations in playing conditions that may impact on the injury profile and account for differences between geographical regions
- Describe the methodology of development of injury prevention strategies in sport
- Determine the effectiveness of current and past injury prevention strategies and how they have impacted on the injury profile
- Describe potential directions of injury prevention strategy

CHAPTER 2

INCIDENCE AND COST OF INJURY IN AUSTRALIAN PROFESSIONAL SOCCER

A paper based on the study in this chapter has been submitted for consideration for publication with the journal Physical Therapy in Sport and is currently under review:

Colagiuri P, Adams, RD, Nicholson LL (2014) Incidence and cost of injury in Australian professional Soccer. *Physical Therapy in Sport* (submitted 21st February 2014)

Incidence and cost of injury in Australian professional Soccer.

ABSTRACT

Objectives: To determine the incidence and cost of injury in Australian Professional Soccer

Design: Longitudinal cohort study

Setting: One regular season of professional soccer competition conducted in Australia and New Zealand in 2009/2010

Participants: 227 male professional soccer players

Main outcome measures: Injury incidence, injury severity, time to injury recurrence, initial injury by quarter season

Results: 71% of players (160) sustained at least one injury, with knee (21%), hamstrings (16%) and hip/groin (16%) the most common sites. Knee, ankle and foot injuries accounted for the most time missed per injury. Initial groin injuries were significantly associated with increased incidence of subsequent injuries to any body region, both within five weeks of return to full participation (p=0.027) and for the remainder of the season (p=0.049). Significantly higher incidence of initial injuries occurred in the first quarter of the season compared with the third (p=0.001).

Conclusions: Hip/groin injuries predisposed players to subsequent injuries suggesting that prevention programs and rehabilitation after return to sport following hip/groin injury may be valuable. Players were more likely to sustain an initial injury early in the season; indicating the need for research on pre-season preparation and off-season rest.

Keywords: Football, Soccer, Hip, Groin, Injury Incidence

INTRODUCTION

Sport participation can confer numerous benefits for the Australian population, with success at an elite level correlating to improved community perception of well being and increased participation in sport at a community level, leading to improvements in health and reduced healthcare costs (Economics, 2009). Increased participation rates place greater numbers of players at risk and increases the potential impact of injury, heightening the importance of optimal injury management, and highlighting injury surveillance as the first step in the injury prevention process (Finch, 2006).

Sports injury surveillance is conducted to monitor injury rates and to inform prevention programs (Finch, 2006; Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001) and has resulted in changes to rules aimed at reducing the rate of specific injuries (J. Orchard & Seward, 2002). Football (or soccer in some regions, including Australia) is the world game played by 208 member countries of Federation Internationale de Football Associations (FIFA). Soccer is the most popular of the four football codes among Australians aged 15 years and over (Australian Bureau of Statistics). Research on soccer-related injury has been undertaken throughout Europe, Africa, North and South America (Hagglund et al., 2003; Hagglund, Walden, & Ekstrand, 2005; Hawkins et al., 2001) with some studies directly comparing injury rates across different countries (Hagglund, Walden, & Ekstrand, 2005). To date, however, no studies have reported injury surveillance in Australian professional soccer. Without injury data, the cost of lost player wages due to injury cannot be calculated. While validated prevention programs may be the ultimate aim of this process, surveillance can assist in identifying players at risk of injury and guide the medical team’s efforts in monitoring at-risk players (Finch, 2006).

Soccer-related injury statistics reported elsewhere in the world cannot readily be generalised to the Australian situation. The Australian style of play, described as "highly competitive physically" (Foster, 2008), the climate, frequency of games, duration of the season, and differences in pitch surfaces and ground hardness may contribute to a higher incidence.

Differing definitions of "injury" also confound attempts to compare soccer-related injury statistics from other regions around the world. European studies report inconsistent patterns of injury occurrence across the competition season, with some finding an early season bias towards injury (Faude, Junge, Kindermann, & Dvorak, 2005) whereas others found more consistent rates of injury across the season (Arnason, Engebretsen, & Bahr, 2005). Several studies have examined one diagnosis or region of injury, finding that the majority of injuries occur in the early months of the competition season (Elliott, Zarins, Powell, & Kenyon; Kofotolis, Kellis, & Vlachopoulos, 2007; Woods et al., 2003) and citing insufficient emphasis on preparatory neuromuscular coordination, strength training and cardiovascular conditioning as reasons. Following an initial injury, athletes could be at increased risk of injury elsewhere in the kinetic chain (Verrall, Slavotinek, Barnes, Fon, & Spriggins, 2001) although there is only limited supporting evidence for this hypothesis.

Injury impacts on short-term health of the player, may affect ongoing participation, and influence socio-economic status through career progression and team selection. It also has financial affects on the player's employer, their club. Without injury data, the cost of losses due to injury cannot be calculated.

The current study aimed to determine Australian professional soccer-related injury distribution, incidence and severity - including the player salary-related financial consequences of injury in the 2009/2010 season. We hypothesised that specific injuries can predispose a player to further injury during both the immediate recovery phase and the remainder of the season.

METHODS

Professional, full-season players from all nine Australian and one New Zealand A-League teams participated in the study. This level of soccer was selected to enable comparison to existing international studies of injury rates (Ekstrand, Hagglund, & Walden, 2011; Hagglund et al., 2003; Hagglund, Walden, & Ekstrand, 2005); the A-League have medical staff and facilities to support reporting procedures. The competitive season spans 33 weeks, commencing in winter, with the majority of the season played during the Australian spring/summer seasons. The full season includes 27 regular games over 28 weeks and up to four games of finals over five weeks. Teams are able to temporarily promote players from their youth team to the A-League team for tactical reasons or to cover A-League player absences. Where a player is listed on the Football Federation Australia's (FFA) long-term injury list (where the player is not expected to return to match play for six or more weeks), the team may recruit a replacement player external to the club on a short-term contract. Data from any player who was engaged with an A-League team for less than 20 weeks of the full season were excluded from the analysis. Players involved with the clubs for less than 20 weeks are often used to temporarily replace an injured player and typically play less than six games.

The mandatory reporting requirement of FFA, the sport's governing body in Australia, is for each team's medical staff (usually comprising of a doctor and physiotherapist) to document all injuries weekly. Injury data were submitted to the FFA via a customised electronic submission system to record each player's game and training load and details of any injury. This Excel-based injury surveillance system was developed by author PC specifically for the FFA and the A-League competition. It was customised with information relating to each club's playing roster and amended squad and injury details based on the previous week's submission. Scope for open-response comments was provided to allow medical staff to provide further information on an injury or absence. Training on the use of the injury surveillance spreadsheet as well as discussion on definitions and categories of injuries was conducted by the first author and also undertaken by team medical staff during the FFA sports medicine meeting held prior to the commencement of the season. Team medical staff were contacted by the FFA's Head of Medical Services during the pre- and early season to discuss any initial difficulties with classifying injuries or use of the spreadsheet.

For each player, weekly data collated included: game time (including the reason for missed game/s including injury, illness and playing for national team), training sessions missed or restricted (including reason), injury occurrence (initial episode or recurrence), injury setting (game, training and 'other' including non-team fitness training and activities of daily living) and injured region (including side affected). Clearance to return to full training implied medical clearance and denoted the conclusion of an injury episode (Fuller, Bahr, Dick, & Meeuwisse, 2007). An open-response comments section provided an opportunity for medical staff to provide additional details such as scan results, details of surgery or clarification of a player's situation (eg. working visa issues). The injuries incurred were reported as affecting any of 14 anatomical regions to reduce the effect of clinical decision-making and diagnosis. To resolve difficulty in defining the hip and groin, this region was divided into regions, as described by Holmich (2007) and Bradshaw et al (2008). Medical staff could select from "anterior hip region", "lower abdominal region", "pubic region" and "adductor region". Player names were replaced with codes by an FFA data collector to maintain confidentiality.

For the purposes of this study, an injury was defined as any physical problem that caused a player to be unable to fully participate in either a training session or a game on any day subsequent to the day of injury. This definition identifies any player with a deficit that impacts on their performance, limiting them from fully participating in a game or training session on any day subsequent to injury occurrence (Hawkins et al., 2001). Weekly submissions were entered onto a spreadsheet where players were considered as individuals as well as grouped by teams. Injury incidence and severity were tabulated by player and week and then summated using an aggregate of injury incidence and severity. Severity of injury was quantified by the number of weeks that a player was listed as injured. Injury severity was not divided into categories of “mild”, “moderate” and “severe” due to the arbitrary nature of the division between classifications. The cumulative probability was then calculated for comparative injury proportions.

Data analysis determined the incidence of subsequent injury within the same full season, regardless of whether the subsequent injury was sustained to the same body region as the original injury or not. Analysis also determined the incidence of sustaining a second injury within 5 weeks of returning to full participation in training and/or games. The 5-week period was selected based on observations and feedback from players indicating that cardiovascular fitness (“match fitness”) may not have been fully regained until the 6^{th} week. Statistical significance of differences between each body region and all other body regions was calculated using the Z test for the significance of the difference between proportions. For results by team, standard deviations, medians and interquartile ranges were calculated.

The proportion of previously uninjured players who sustained an initial injury was calculated to determine whether the incidence of injury significantly differed in each quarter of the regular season. The first week of the regular season was excluded from analysis as performance-affecting injuries incurred prior to week one were recorded in this week. Statistical significance of differences in injury proportions over quarters was calculated using the Z test for the significance of the difference between proportions.

In addition to the personal cost to a player of being out injured, the loss of a player's productivity is seen as a loss of investment, as the player is unproductive with respect to team outcomes during this time, and a replacement player may incur additional cost. In the absence of individual player salary data (due to confidentiality), this loss of investment can be quantified by using the average player salary, as this figure may enhance the justification for prevention programs as a method of reducing financial loss, rather than justifying financial investment in programs with non-financial statistics. An average player salary can be calculated by dividing the team's salary cap (maximum value of team's player salaries excluding the marquee player, set by FFA as the governing body) by the average number of players per team. The salary cap was A$2,350,000 for the 2009/2010 season and there were an average of 21.5 players per team (excluding the marquee player). The exclusion of the marquee player's salary ensures that average salary values are not overestimated, therefore the player salary cost of injury should be considered an underestimate of its true value. The standard error of the player salary cost of each injured region was calculated using the standard error of a proportion.

RESULTS

During the 2009/2010 A-League season, 10 teams comprising of 265 players were followed. 38 players with less than 20 weeks of involvement were excluded and no players refused to participate. 227 players were included in the data set. One player changed clubs mid-season, however as his injury surveillance was continuous throughout the season, he has been included as a full-season player. Over the course of the season, 294 weekly reports were expected and 275 were received. Ten of the 19 missing reports coincided with the Christmas/New Year period when players were not competing and had a reduced training schedule but were not followed by medical staff and nine reports were missing due to staffing changes at one of the clubs.

Injuries were sustained by 160 players (71%) during the season, with 60 players (26%) sustaining one injury, 65 (29%) sustained two injuries, 23 (10%) sustained three injuries, 9 (4%) sustained four injuries, two players sustained five injuries and one player sustained six injuries. Of the 100 players (63%) who sustained more than one injury within the same season, 48% of the subsequent injuries occurred within five weeks of return to play (Figure 1).

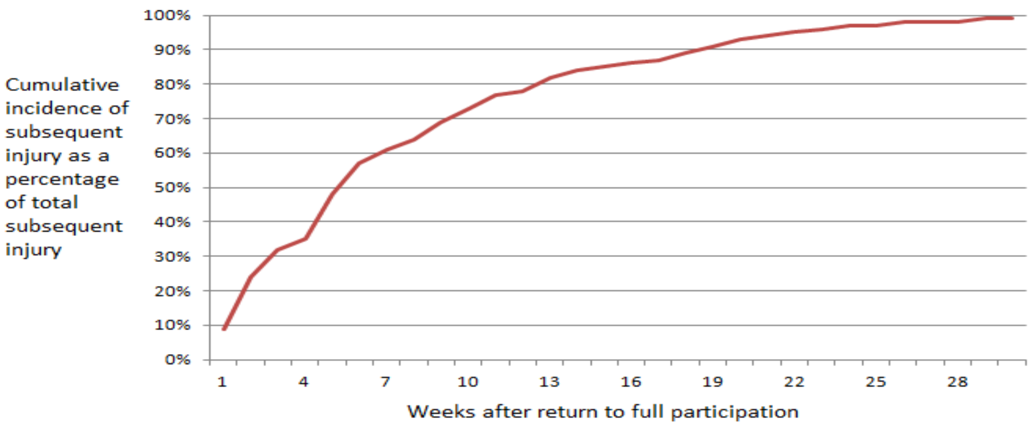
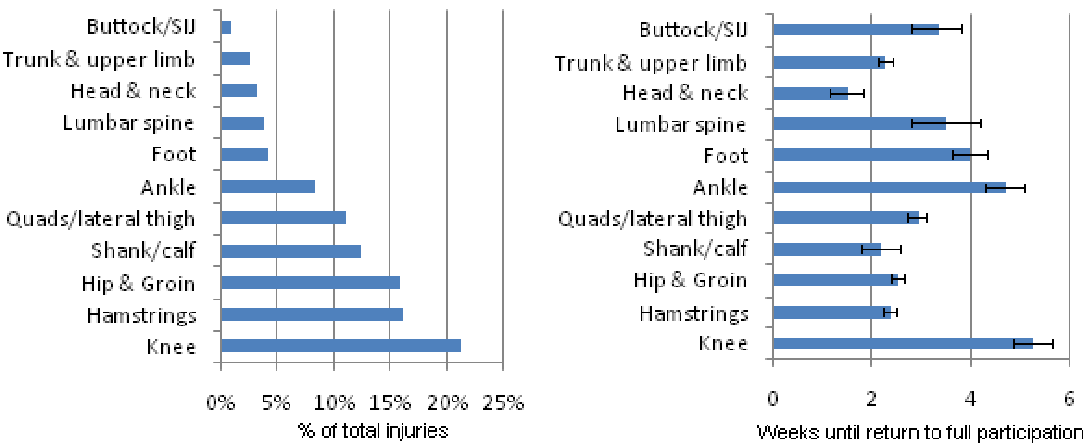


Figure 1: *Accumulated percentage of subsequent injuries by weeks after return to full participation, expressed as a percentage of total subsequent injury.*

The average injury incidence was 1.9 injuries per injured player for the season (SD 1.0, median 2, interquartile range [IQR] 1-2). The mean new and recurrent injury incidence per team was 31.4 injuries (range 16-45, SD 9, median 32, IQR 27-41). The most commonly injured regions for the whole A-League were the knee (67 injuries, 21% of all injuries), hamstrings (51, 16%) and hip/groin (50, 16%) (Figure 2a). Knee injuries included 11 anterior cruciate ligament (ACL) injuries, which represents 4% of all injuries and 16% of all knee injuries. Of the 50 hip/groin injuries, 31 (62%) were reported as adductor-related.

During this season, players were listed as “injured” for an average of 6.6 weeks per injured player (SD 6.2, median 5, IQR 2-8) and 3.4 weeks per injury (SD 4.2, median 2, IQR 1-4), both of which are positively skewed as expected. On average, 35.6 players were listed as injured each week during the regular season, excluding finals. Injury to the knee, ankle and foot regions accounted for the greatest number of weeks with missed games, training and/or restricted training per injury resulting in 5.2, 4.7 and 4.0 weeks respectively.



a *b*

Figure 2 *a) Injury incidence (initial and subsequent injury) by region expressed as a percentage of total injuries. b) Injury severity by region expressed as average weeks until return to full participation.*

Injuries of the ACL resulted in the greatest loss to participation with a mean severity of 15.2 weeks. Excluding ACL injuries, players with knee injuries lost on average 3.5 weeks of participation.

Of the 29 players who incurred an initial hip/groin injury, 22 (76%) sustained a subsequent injury later in the competitive season (6 subsequent hip/groin injuries, 16 subsequent injuries to other body regions). In a directional test, this was significantly higher (Z=1.643, p=0.049) when compared with the 60% of players who sustained a subsequent injury following an initial non-hip/groin injury.

Similarly, incidence of subsequent injury within five weeks of returning to full participation was significantly higher in a directional test (Z=1.926, p=0.027) after an initial hip/groin injury compared with initial non-hip/groin injury. Of the players with an initial hip/groin injury (n=29), 13 (45%) sustained a subsequent injury (3 subsequent hip/groin injuries, 10 subsequent injuries to other body regions) within the five weeks compared with the 26% of players who sustained subsequent injury after initial non-hip/groin injuries.

A significantly higher injury incidence was evident in the first quarter of the season compared with the third quarter (Z=3.75, p=0.001) based on the percentage of previously uninjured players sustaining initial injuries in each quarter of the season. There were 60 initial injuries sustained in the first quarter and 14 initial injuries sustained in the third quarter, representing 26% and 10% respectively of uninjured players at that point in the season. The injury incidence in the second quarter and last quarter were not significantly different (Z=0.26, p=0.80) with 29 and 23 injuries incurred respectively (17% and 19% of uninjured players).

The estimated financial loss incurred in wages paid to players listed as injured was A$3.4M across the A-League, based on a team salary cap (maximum value of team's player salaries excluding the marquee player). This represented a loss of 15% of total player wages based on the salary cap. The range of lost player wages per team was A$153k – A$488k, representing 7% - 21% of the teams' salary cap (SD A$124k, median A$336k, IQR A$269k-A$477k).

The most costly injury was ACL rupture, accounting for A$646k in lost player wages, and the most costly region was the knee, accounting for A$1.1M (including A$257k for MCL injuries and A$646k for ACL injuries) (Figure 3).

Injuries in shank/calf, hamstrings, hip/groin and ankle regions also proved costly, with associated lost player wages of A$393k, A$388k, A$377k and A$317k respectively. The shank/calf figure includes one player with a complete Achilles tendon rupture early in the season, costing A$103k. This is a season-ending injury, requiring surgery and a prolonged rehabilitation phase and recovery time.

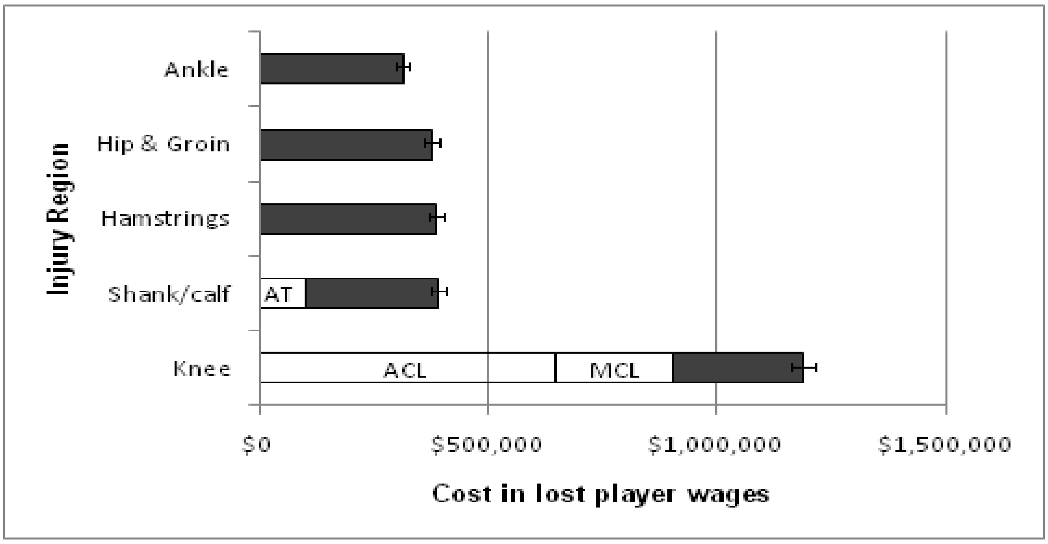


Figure 3: *Direct financial cost of injuries by region expressed as lost player wages in Australian dollars. (AT: Achilles Tendon, ACL: Anterior Cruciate Ligament, MCL: Medial Collateral Ligament)*

DISCUSSION

The data collected here showed that incidence of subsequent injuries to any body region following an initial hip/groin injury (76%) was significantly higher than it was after initial non-hip/groin injuries (60%). In contrast, the incidence of all injuries was similar for a player's initial (71%) and subsequent injuries (63%) within the season. This finding has important implications for the integral role of the hip/groin in the production of high-level skills required of soccer players. One explanation for this elevated subsequent injury incidence is an altered neuromuscular control following hip/groin injury. This account is based on the view that the hip/groin is central to stability and force generation in single leg (predominantly kicking) lower limb activities. The increased incidence may be due to the inability of currently adopted clinical and functional testing to determine the optimal timing of return to sport after hip/groin injury. The elevated risk of subsequent injury for the remainder of the season justifies a heightened vigilance following initial hip/groin injury and ongoing injury prevention programs specific to affected players.

Players with hip/groin injuries had a lower than average time to return to full participation (2.5 weeks, compared to the overall average of 3.4 weeks per injury) suggesting that lost match fitness due to extended absence from training and games is an unlikely explanation for subsequent injury. This shorter recovery time may increase the risk of subsequent injury due to insufficient time for healing and comprehensive rehabilitation. Further, examination of the validity of return to play criteria utilised after hip/groin injury may be required.

Timing of initial injury incidence showed a significantly increased incidence in the first quarter (26%) relative that in the third quarter (10%). The findings of the current study relating to the first quarter of the season may reflect reduced fitness levels predisposing players to injury due to fatigue. An increased incidence of injury in the first quarter of the season highlights the necessity for the implementation of effective injury prevention programs in the pre-season period.

Estimated lost player wages due to injury was calculated using the salary cap, which excludes the salary of the marquee player who does not fall under the salary cap restrictions as they are paid substantially more than other players and their inclusion would raise the average player wage well above an approximation of the earnings of an average player. Had the marquee player sustained an injury, the cost could be more than ten times greater per game than the team's average player wage based on the salary cap. Despite the conservative estimate of lost player wages with the exclusion of the marquee player's salary, this figure represents a substantial portion of club revenue and provides a financial quantification of one aspect of the impact of player injury. This should justify capital investment in injury prevention programs as a means of minimising financial loss at club level.

The variation in weeks lost to injury between teams may be explained by conservative rehabilitation and return-to-play decisions of medical and coaching staff, and by the types of injuries sustained. The independent nature of the clubs and their medical staff and the perceived "value" of the affected players mean that return-to-play decisions will not be consistent. The return-to-play approach of the medical staff will affect the results of injury surveillance where a more conservative approach may result in a longer period off-field per injury, seen as increased severity per injury, however less cautious approaches may present lower severity. The total number of weeks lost to injury per team may provide a better means for comparison however this quantity is greatly affected by the nature of the injuries sustained in each team.

Two of the 10 teams included three players who sustained season-ending ACL injuries, substantially increasing their weeks lost to injury. For ACL injuries, the average of 15.2 weeks lost to injury reflects the time remaining in the season from the date of injury rather than the expected recovery time. One study allocated six months of time lost to each ACL injury despite the recovery period falling outside the end date of the competition (Hagglund, Walden, & Ekstrand, 2009). This approach may avoid the issue of ACL-related absences being unrealistically shortened if they occur late in the season however other season-ending injuries such as Achilles tendon ruptures and some fractures were not allocated the same allowances.

The definition of injury employed in the current study is based on the model adopted by the Football Association (governing body of English football), where a player is deemed injured if they are unable to participate fully in team activities after the day of injury (Hawkins et al., 2001). It is consistent with the American National Athletic Injury Registration System (NAIRS) which defines injury as reportable if it “limits athletic participation for at least the day after the day of the onset” (Junge & Dvorak, 2000). Injuries were classified by region rather than by diagnosis however specific diagnoses were required for types of injuries where the diagnosis may have a high impact such as ACL and Achilles tendon ruptures.

Unlike our injury definition, the “medical attention” definition of injury used in some studies (Junge, Dvorak, & Graf-Baumann, 2004; Morgan & Oberlander, 2001) may include player complaints of minor soreness that are insufficient to affect performance and may be attributable to fatigue or minor contact without an underlying pathology. The “game missed” definition (J. Orchard & Seward, 2002) was not used as it does not account for injuries with a recovery time shorter than the time between two matches and where players are unable to train but play at least a part of a game due to tactical considerations. While the “game only” definition is easily audited for accuracy and requires less information from team para/medical staff, the information may not fully capture the impact of the injury on the player's ability to perform. These inconsistencies in injury definition hinder comparison of injury incidence and prevalence across studies and consensus is required for meta-analysis.

The injury definition utilised by this study may also affect the outcome of the surveillance where a team may schedule a training session the day after a game whereas another team may allocate this as a rest day. Where a player's performance is limited only on the day subsequent to the game, one team would record an injury whereas the latter team would not as the player would not have been unable to participate in the first team session scheduled two days after the game.

For this season, 11 ACL injuries were incurred exceeding the injury incidence expected based on seasonal data from overseas injury surveillance. However, lower limb (including hip/groin) injuries accounted for 90% of all injuries and the proportion of injuries for each region were close to the corresponding reported incidence of injury in European leagues, with Australian incidence of knee, hip/groin and thigh injuries marginally higher and ankle injuries slightly lower (Hagglund, Walden, & Ekstrand, 2005; Hawkins et al., 2001; Junge et al., 2000).

Participating medical team staff reported satisfaction with the injury reporting system based on enquiries made during phone and personal conversations with the FFA's Head of Medical Services. The reporting requirements were unambiguous through provision of the currently-utilised injury definition on each weekly team spreadsheet in addition to providing injury classification options on drop-down menus.

The failure of two clubs to provide training time per week data, resulting in an inability to calculate exposure rates for injury, was a limitation of this study. Due to staffing changes in one club, data for a period of nine weeks could not be collected. Collecting individual player data such as age, experience and anthropometry may have permitted more detailed analysis, however these variables were beyond the scope of this study.

Injury data has not been analysed by individual team as the goal of the study was to present injury data for the A-League as a whole, as the first published study on the Australian professional soccer competition. Future studies may wish to undertake sub-group analysis by team in order to identify injury patterns that may warrant further investigation.

This study highlights the player salary-related cost of injury and the key anatomical regions of injury to inform the next stage of the injury prevention model. It would be premature to suggest prevention programs based on the results of injury surveillance before further research is undertaken to investigate the potential reduction of first and subsequent injury and their associated costs through altered or additional training methods, and/or improved provision of medical services. Identification of risk factors for key injuries and injured regions would also assist by providing potential focuses for the design of prevention programs.

CONCLUSION

Although Australian soccer is often characterised as having more physical contact than other regions around the world, the injury incidence found in this study of Australian professional soccer/football is similar to that reported in European professional football, with the highest incidence occurring at the knee, hamstrings and hip/groin. The incidence of subsequent injury to any body region after an initial hip/groin injury and the incidence of subsequent injury within five weeks of an initial hip/groin injury were significantly higher than for any other injured region, indicating that hip/groin injuries may warrant closer scrutiny in assessing fitness for return to play and monitoring after return to play. Further analysis of predictive variables of subsequent injury after an initial injury and predictive variables to determine safe return to play are required. The financial impact of injury in terms of lost player wages is considerable and justifies expenditure in the areas of prevention programs and evaluation of current systems of player management.

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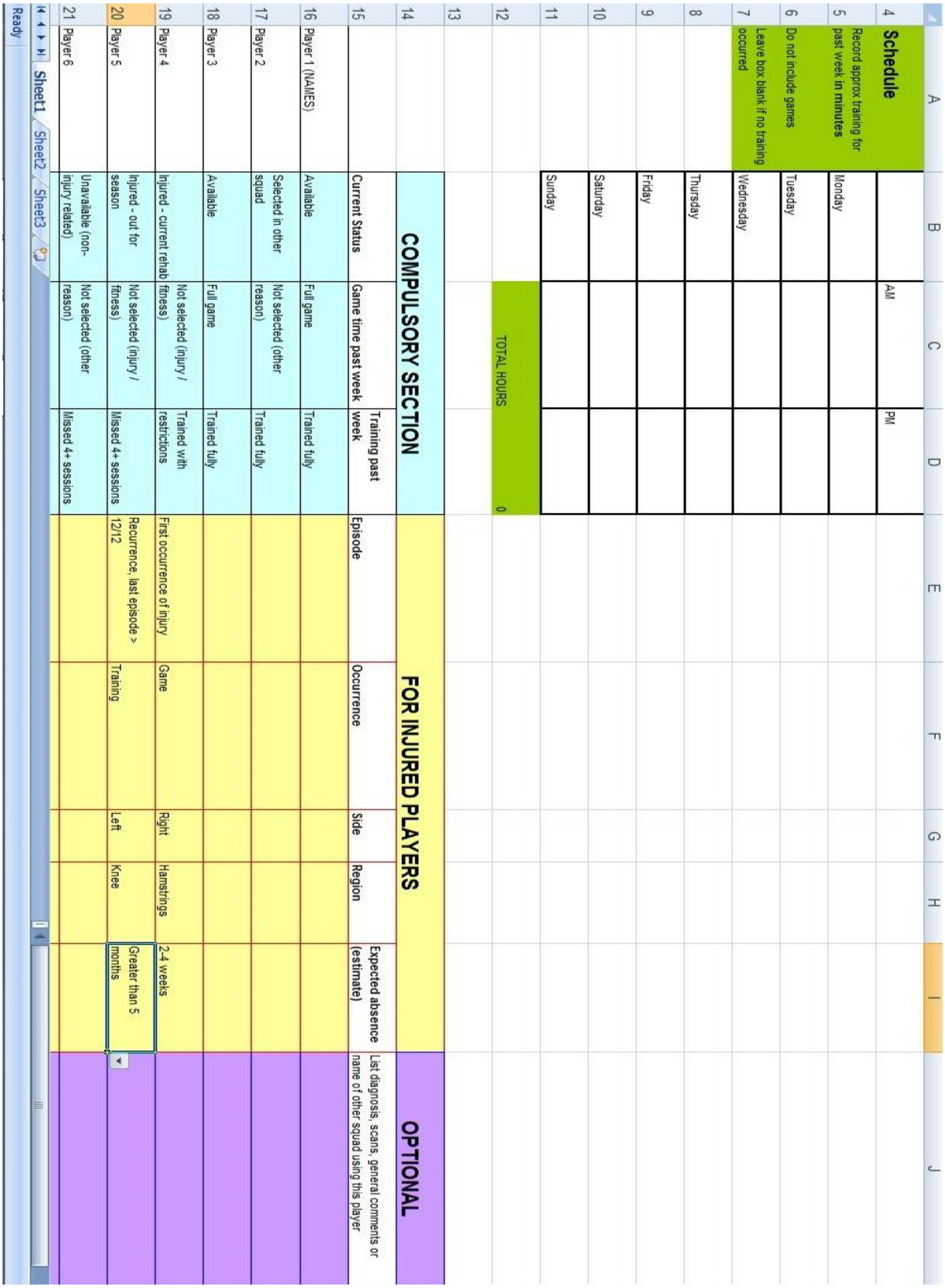

	A	B	C	D	E	F	G	H	I	J
4	Schedule		AM	PM						
5	Record approx training for past week in minutes	Monday								
6	Do not include games	Tuesday								
7	Leave box blank if no training occurred	Wednesday								
8		Thursday								
9		Friday								
10		Saturday								
11		Sunday								
12			TOTAL HOURS	0						
13										
14		COMPULSORY SECTION			FOR INJURED PLAYERS					OPTIONAL
15		Current Status	Game time past week	Training past week	Episode	Occurrence	Side	Region	Expected absence (estimate)	List diagnosis, scans, general comments or name of other squad using this player
16	Player 1 (NAMES)	Available	Full game	Trained fully						
17	Player 2	Selected in other squad	Not selected (other reason)	Trained fully						
18	Player 3	Available	Full game	Trained fully						
19	Player 4	Injured - current rehab	Not selected (injury / fitness)	Trained with restrictions	First occurrence of injury	Game	Right	Hamstrings	2-4 weeks	
20	Player 5	Injured - out for season	Not selected (injury / fitness)	Missed 4+ sessions	Recurrence, last episode > 12/12	Training	Left	Knee	Greater than 5 months	
21	Player 6	Unavailable (non-injury related)	Not selected (other reason)	Missed 4+ sessions						

Sheet1 Sheet2 Sheet3

Ready

Supplementary Figure (for e- version only): Screenshot of electronic data collection form with sample information

CHAPTER 3

CONCLUSIONS AND FUTURE DIRECTIONS

Concluding remarks

Injury surveillance is an important component in the injury prevention process (Finch, 2006). It informs the next stage of the prevention process and is used to evaluate the effectiveness of an intervention (Finch, 2006). Difficulty can arise when interpreting and comparing injury surveillance data due to a lack of consistency in both the definition of injury and the determination of completion of an injury absence (Hagglund, Walden, Bahr, et al., 2005). The current study reveals several similarities when comparing anatomical distribution of injury to European data however there are marked differences with regard to duration of injury absence from training and the injury setting. The player salary cost of injury is unique to the current study and allows a financial (albeit likely underestimated) value to be assigned to injuries to assist in justifying investment in prevention methods.

Successful prevention programs are one of the primary goals of injury surveillance. Prevention methodology may seek to change a modifiable risk factor, by implementing a preventative exercise program, or to protect against a non-modifiable risk factor by recommending amendments to governing rules.

Logically, prevention programs should initially focus on injuries that have been selected based on their frequency of incidence or on the severity of their consequences. The current study found a high incidence of knee injuries that had a significant impact on players due to prolonged recovery periods. Incidence of injuries to the hip/groin region were also high, albeit associated with faster recovery times but importantly, these were a risk factor for increased incidence of a secondary injury to any body part for the remainder of the season.

Anatomical distribution of injury

In a team-based contact sport such as soccer, where the goal is to contest for control of the ball using any body part other than the hands, injury occurs to all parts of the body. Due to the kicking and pivoting nature of the game, a strong bias towards lower limb injuries is expected. Studies have typically reported variation in areas of injury across body segments with slightly elevated percentage of injuries in one region (eg. the knee) and an equivalent reduction in adjacent regions (eg. the ankle) (Klugl et al., 2010; Tegnander, Olsen, Moholdt, Engebretsen, & Bahr, 2008). Despite this variation, most studies report consistent proportions of lower limb injuries relative to total number of injuries (Arnason et al., 2004; Klugl et al., 2010). The anatomical distribution and incidence of injury found in the current study is comparable to European professional soccer data with thigh (hamstrings, quadriceps and lateral thigh) injuries representing 27%, knee 21% and hip/groin 16%, of overall injuries. Similarly, Arnason et al (2004) reported incidences of 24%, 16% and 13% in 306 players and Hawkins et al (2001), studying 2376 players, reported incidences of 23%, 17% and 12% respectively.

Variation in injury incidence data between studies may exist, in part, due to difficulty in clearly differentiating adjacent anatomical regions and identifying a pathological structure when diagnosis is clinically challenging, for example when the pain distribution of an anterior hip pain may overlap with a proximal quadriceps strain (Brooks & Fuller, 2006; Holmich, 2007). When there may be some confusion with definition of the pathological structure, it may be more practical to assign clinical entities based on pain behaviour and clinical presentation (Bradshaw et al., 2008; Brooks & Fuller, 2006; Holmich, 2007). In the current study, the groin region was divided into adductor, pubic, lower abdominal and hip regions in an attempt to improve inter-rater reliability of allocation of injury to anatomical regions.

Injury definition

The injury definition is a defining element of injury surveillance and the definition used can affect the results and their comparability to results of other surveillance studies (Hagglund, Walden, Bahr, et al., 2005). To date, consensus on defining injury has not been reached (Brooks & Fuller, 2006; Hagglund, Walden, Bahr, et al., 2005). For the current study, a “time loss” definition was selected as it more appropriately reflects the impact of injury on the team. This definition allowed measurement of the amount of time that a player was at a reduced capacity for games or training due to injury and can quantify the severity of injury in days rather than weeks. The injury definition also required that the player be affected on the day after the injury occurrence, to ensure any soreness that resolved on the same day was not mistaken as injury. A “games missed” definition of injury is readily audited, however it lacks validity as it fails to account for the impact of injury on the period between games. As a consequence, injury severity is quantified in weeks rather than days and may miss injuries with an absence of less than the period between games. The current study also avoided definitions that relied on access to medical imaging, such as a “tissue injury” definition, as the availability of such imaging is not uniform across the competition and imaging is not routine with all injury-related absences, making it difficult to maintain a consistent injury definition based on imaging findings.

Injury severity

Injury severity is a complex construct. From a health professional’s viewpoint, it may be defined by the relationship between the extent of tissue damage and the rate at which that tissue can be expected to heal. From the injured player’s perspective, it can be defined as the extent of the symptoms experienced, the impact that the injury has on activities of daily living and recreation as well as the impact it has on earning capacity and career opportunity/progression. From the perspective of the player’s employing club, it is likely that severity is perceived as the time frame for return to unrestricted playing, and as a specific cost to the club. As the health professionals' and players' definitions are difficult to quantify, the choice was made to define injury severity as the number of days that a player is listed as injured. According to Hagglund and colleagues (Hagglund, Walden, Bahr, et al., 2005) this definition is commonly used in injury surveillance studies to quantify the magnitude of an injury relative to another injury or injury setting. The decision for the current study was to maintain the quantification of injury severity as a number of days rather than categorising it based on the somewhat arbitrary classifications of mild, moderate and severe. A comparison of injury severity between anatomical regions is best presented in numerical form as this minimises the data lost in conversion to descriptive categories.

The current study found average injury severity to be similar or higher when compared to European surveillance data. Compared to the current study's average injury severity of 23.8 days absence per injury, Hawkins et al (2001) found an average of 24.2 days for English professional soccer. However, Hagglund et al (2005) reported that the average number of days absence after injury for players in Denmark and Sweden was 11.8 and 13.1 respectively. This inconsistency may be explained by variations in return-to-play criteria, injury management and the return-to-play decision-making process. More complex factors include pressure from club management and perceived pressure on the player from the player's agent due to current or future contract negotiations. This pressure may lead to the player under-reporting symptoms in an effort to minimise the injury's apparent severity, allowing them to appear to be a more valuable member of the team and providing them with more bargaining power when negotiating their playing contract or contract extension.

Variation exists in the definition of a player's return to participation and cessation of the injury episode. In the current study, a player was no longer considered injured after participation in a full team training session or game. Hagglund et al (2005) considered an injury episode to have concluded once the player was cleared by medical staff to return to full training or games. Hawkins et al (2001) did not state their criteria for conclusion of an injury episode.

An expedited return to play may be due to a range of factors. Provision of immediate access to medical diagnostic facilities may be one such factor (Ball & Haddad, 2010). The unrestricted availability of medical imaging may guide the rehabilitation process by confirming the diagnosis, including the grade of injury, and give an indication of the structural risk of re-injury. This may allow medical staff to refine their clinical decision making and offer greater confidence when determining the intensity of rehabilitation.

The number and experience of medical personnel may also influence the availability and diversity of medical treatments on offer to an injured player. Increased frequency of treatment could improve the recovery time of an injury, although this does not hold true for all injuries. Greater diversity of medical services on offer should assist in providing the most effective treatment for a broader range of injuries.

The decision making process for determining a player's return to full participation can influence both the duration of the individual injury episode as well as the number of injury recurrences experienced by the team (Heiderscheit, Sherry, Silder, Chumanov, & Thelen, 2010). This includes the decision maker's experience in return-to-play assessments, adoption of clear return-to-play algorithms and a focus on player welfare rather than team performance. Higher risk return-to-play decisions are one factor that may increase the risk of injury recurrence within the playing season.

Varied definition of what constitutes an injury recurrence is another factor that may affect the incidence and severity of injuries reported in a study (Hagglund, Walden, Bahr, et al., 2005). This may apply to a repeat episode of the same injury within the same season or an episode of an injury that the player has previously suffered during their playing career. Requiring a player to disclose their injury history often introduces inaccuracy and recall bias (Engstrom, Johansson, & Tornkvist, 1991; Gabbe et al., 2003; Valuri et al., 2005). Such reporting assumes that the player both understands and remembers their previous diagnoses. It is not uncommon for a player to remember an ankle sprain that limited their participation for an extended period, however it may also be that they cannot recall which ankle was affected, which ligaments were injured and what was the duration of the participation restriction. In addition, the player may have concerns regarding both confidentiality and possible ramifications of past injuries on selection. Attempts to discover a more accurate player injury history from medical records can also prove difficult due to the involvement of multiple clubs, each with multiple practitioners involved in each player's medical care.

The injury setting

There are a number of factors that can impact on injury incidence and severity including the style of play typical to the region, the climate experienced, the ground type/surface as well as various aspects of the medical services provided to players. These can influence the injury distribution by season quarter and the proportion of training injuries relative to overall injuries.

The incidence of initial injury by season quarter is multi-factorial. The data from our study is consistent with some studies from Europe (Engstrom et al., 1991; Hawkins & Fuller, 1999; Hawkins et al., 2001; Klugl et al., 2010; Woods et al., 2003) however their studies are not consistent with other European studies (Engstrom, Forssblad, Johansson, & Tornkvist, 1990; Gabbett, 2000; Walden et al., 2011). Some factors that potentially affect the injury incidence by quarter are climate, player conditioning and tactical considerations.

Climate

Climate may generate a higher (or lower) injury incidence as both colder (Walden et al., 2011) and warmer (J. W. Orchard et al., 2013) climates are associated with increased risk of injury (J. W. Orchard & Powell, 2003). Climate may impact on injury occurrences as colder climates tend to be associated with reduced rates of ankle and knee injuries in some sports (J. W. Orchard & Powell, 2003) and an increased risk of muscle injury without adequate warm-up (Mohr et al., 2010). There has been recent evidence that appears contradictory, with Orchard et al (2013) finding that warmer Australian climates produce a greater number of injuries in the Australian Football League and Walden et al (2011) finding cooler Northern European climates produce a greater number of overall injuries in soccer compared to warmer climates (Mohr et al., 2010). Further research is required to determine whether the conflicting results are due to the differing demands of each sport or whether temperate climates produce lower injury rates and any variance, warmer or cooler, increases injury rates in cooler climates (Mohr et al., 2010) due to changes in muscle extensibility (Walden et al., 2011) or in warmer conditions due to early fatigue (Frisch et al., 2011; Mohr et al., 2010).

The method of data collection for the current study utilised technology in the form of an Excel spreadsheet due to the amount of information it is able to collect while maintaining its simplicity. Further technological advances have made it possible to collect even greater volumes of data with improved simplicity due to the functions of a smartphone application, or app, where data such as temperature and rainfall can be automatically recorded by the app. This would provide accurate and consistent data on weather conditions to allow analysis of its impact on injuries. It should be noted that climate and weather are distinctly different and collection of weather information would allow analysis of injury relative to weather conditions only.

Player conditioning

Player conditioning can also have an effect on injury incidence with less conditioned players more at risk due to fatigue and lack of strength (Frisch et al., 2011). This will most commonly be found where there is a lack of sufficient pre-season training (Ronnestad, Nymark, & Raastad, 2011) or where the pre-season period is not of sufficient duration. It could be expected that a lack of conditioning would have a greater impact on injuries during periods of congested match fixtures, with a greater number of game injuries incurred during periods of congested fixtures compared to regular match fixtures (Dellal, Lago-Penas, Rey, Chamari, & Orhant, 2013). The difficulty with identifying those at risk of excessive in-season fatigue is that there is no single measure that can quantify a player's conditioning. Additionally, using measures such as endurance tests to exhaustion and regular blood tests within a soccer season would likely contribute to fatigue and could potentially contribute to a heightened risk of injury.

Tactical considerations

Another factor that may impact on injury occurrence is tactical considerations such as style of play and risk-taking behaviour. Australian professional soccer can be characterised by heavy physical contact (Foster, 2008) by comparison to other regions of the world. This style of play involves contact and collisions with greater force than would otherwise be seen and may account for the higher incidence of injuries in the training setting seen in the current study compared to European

(Hagglund, Walden, & Ekstrand, 2005) and American (Morgan & Oberlander, 2001) injury surveillance data.

Risk-taking behaviour may also affect injury occurrence in the last quarter of the Australian professional soccer season as there is a greater period of time from the end of the season until the next scheduled matches compare to their European counterparts. This allows greater injury recovery time and may contribute to a “do or die” attitude seen in the final part of the season, without the consideration of missed matches during an injury absence. Any “time loss” definition is unable to accurately quantify the injury incidence during finals as any injuries sustained in a finals defeat will not result in missed games due to the team’s exclusion from further fixtures.

Training and game injuries

In the current study, 71% of players sustained at least one injury in the season with 35% of all injuries occurring in the training setting. Hagglund et al (2005) studied the professional soccer competition in two European countries and found 67% and 81% of players sustained at least one injury with training injuries accounting for 65% and 69% of all injuries respectively. The variation between the European findings and the findings of the current study may be due to differences in the, climate or training session design. The study by Hagglund et al (2005) documented injuries over a six month period which encompassed pre-season and regular season in Sweden and mid-season and finals period in Denmark, making comparison to regular season results difficult (J. Orchard & Seward, 2002).

Ground type /surface

Ground type has been linked to an increase in ACL injuries, with increased rainfall and reduced evaporation potentially resulting in a denser root bundle and increased surface to shoe grip (Orchard et al., 1999). As the matches of the A-League are played across a wide variety of climates, from the tropical savanna climate of North Queensland to the temperate climates of southern Australia, the variations in ground types could be expected to produce a different distribution of injury. Although the data set of the current study was insufficient to analyse the statistical significance of ground location for ACL injuries, future research could focus on an association between ACL injury and ground location. This may assist in identifying risk factors for ACL injuries including climate and ground type.

Cost of injury

For quantifying the total financial cost of player injury, three categories of economic loss incurred during a player's injury absence were defined; "direct", "indirect" and "hidden" costs. The first, "direct costs", was defined as the average cost of a player's wages, which allows an indicative financial value to be assigned to injury which represents the minimum cost of injury. "Indirect costs" include medical expenses and the cost associated with the provision of additional training sessions for injured players. These would likely vary for each injury occurrence, despite similar diagnoses and recovery time. "Hidden cost" is lost revenue due to a player's absence and includes reduced gate takings, particularly for the absence of any marquis players, and reduced prize monies, where a player's absence may have impacted on the outcome of games in both the regular season and finals. Calculations of hidden costs would be estimates as reduced gate takings are multi-factorial and any effect of an individual player's injury on match outcome could not be predicted with any certainty.

Assigning a cost to each injury occurrence and to specific types of injury across the whole league can assist in justifying further injury surveillance and research. The cost-benefit of preventing an injury can be calculated as a proportion of the cost of injury, enabling economic justification of injury prevention programs to be presented to clubs. This rationale focuses on the potential loss incurred by the club with the financial value of an injury prevention program viewed as a means of potentially reducing this cost. In this model, an effective injury prevention program can be seen as a return on investment with less direct and likely indirect and hidden costs associated with the target injuries.

The injury prevention model

Injury prevention should be one of the primary aims of the team physiotherapist, who will be concerned to eliminate or control factors that may reduce the effectiveness of any initiatives or in-season monitoring. These factors include elements such as the conflicting demands of a player's desire to perform well on the field or the coaching staff's approach to player injury. Players may underreport symptoms of injury or delayed recovery in an attempt to remain available for team selection. The motivation for this is often linked to competition between players for selection to similar positions on the team, imminent contract negotiation periods or selection for representative duties. Coaching staff may also inadvertently have an adverse effect on injury prevention if players perceive a disadvantage when contending for team selection after an injury absence. In these situations, the physiotherapist can take into account the potential underlying influences on the information they utilise to clinically reason and adapt accordingly. The team physiotherapist must also be focused on team performance whilst still maintaining the often contradictory role of medical care provider.

Injury surveillance is an early stage of the injury prevention model providing a baseline measure of injury rates as well as informing and evaluating the efficacy of prevention programs (Finch, 2006). As the injury profile will fluctuate each season (Carling et al., 2010; J. W. Orchard, Chivers, Aldous, Bennell, & Seward, 2005), surveillance data should ideally be collected over a number of years. The next step of the injury prevention model is to identify the most appropriate injuries to target with a prevention program. This is a multi-factorial process with inputs from injury surveillance data, clinical experience and prevention rationale. Injury surveillance can identify the injuries with the greatest impact; that is injuries with the highest incidence or severity or both. Clinical experience is then required to filter the injuries which may not be preventable due to the nature of the sport or other causative factors. The current study indicates that knee injuries, hamstrings injuries and hip/groin injuries account for the greatest number of missed games and would justifiably be the focus of any prevention efforts. Modifiable causes of injury in these regions could be the focus of specific prevention initiatives, although the impact of non-modifiable factors can still be reduced with the use of protective equipment or regulatory changes.

Modifiable and non-modifiable risk factors

Ideally, injury surveillance should quantify the current injury situation as well as begin to identify risk factors that are associated with injury. Although risk factors are not necessarily causal, they provide a starting point for further research into factors that may contribute to injury. These factors can be categorised into modifiable and non-modifiable for the purposes of prevention. Modifiable factors, such as muscle weakness, can be directly targeted by preventative programs whereas non-modifiable factors, such as previous injury, may require measures such as protective equipment or regulatory changes to lessen the injury risk.

The goal of injury prevention is to reduce injury incidence to its lowest possible level by altering modifiable risk factors and mitigating the impact of non-modifiable factors. Modifiable risk factors include elements of the environment such as ground type (Dragoo & Braun, 2010; Hershman et al., 2012; J. W. Orchard et al., 2005) as well as factors relating to the individual such as neuromuscular strength (Frisch et al., 2011;

J. W. Orchard et al., 2005). These risk factors should be targeted based on intervention effect size, cost effectiveness and specific injury risks for players within the team involved. Interventions such as the FIFA 11+ (Junge et al., 2011) and ground type changes (Orchard et al., 1999; J. Orchard, 2002) are examples of preventative measures aimed at modifying factors contributing to injury. The FIFA 11+ is a comprehensive warm-up program for soccer players that involves a combination of running, strength, balance and agility exercises ("The "11+" - FIFA.com,"). Junge et al (2011) showed that the FIFA 11+ program reduce the overall injury rate in amateur soccer players however Gatterer et al (Gatterer et al., 2012) found no significant difference after the implementation of the warm-up program. Different ground types have also been shown to impact injury rates with Orchard et al (2005) finding that changing to a grass type with a less dense root bundle significantly reduced the incidence of non-contact ACL injuries and Dragoo et al (2013) showing that natural grass is associated with a lower incidence of ACL injuries compared to artificial grass.

Non-modifiable risk factors such as climate (Kunz, 2007; J. W. Orchard et al., 2013; Walden et al., 2011), player age and past history of injury (Arnason et al., 2004) should be taken into account when considering a team’s injury risk profile, and measures should be undertaken to reduce the exposure to these factors. These measures may include clothing and hydration strategies appropriate for the climate, bracing of previously injured areas and reduced match time for older players.

<u>Rule changes</u>

One aspect of sport that is potentially modifiable is the governing rules, although this becomes more difficult as the number of stakeholders grows. Soccer is governed by FIFA, which has 208 member countries and over 265 million players worldwide (Kunz, 2007). The sheer size of the organisation makes rule changes to reduce the risk of injury relatively difficult. While rule changes have occurred in past years, they are typically altered to improve fairness or to enhance the spectators' experience. More region-specific sports with fewer participants, such as Australian Rules Football (AFL), have less regulatory barriers to rule change. As a result of AFL injury surveillance, some rules changes have been identified and successfully implemented to reduce the incidence of injury (Orchard & Seward, 2009). While this study did not have sufficient data on the circumstances of each injury to advocate for any rule changes, it could provide baseline data to evaluate the effects of any rule changes.

Injury prevention programs

Logically, pre-season training will focus on injury prevention as much as performance, targeting fitness, skills and general factors such as body weight. Currently, it is thought that the training should also include exercises specific to prevention of key injuries for the sport played and for the individual. Targeted exercise programs have been shown to be effective at reducing the incidence of common injuries such as hamstring muscle tears in elite male soccer players (Askling, Karlsson, & Thorstensson, 2003) and major injuries such as Anterior Cruciate Ligament rupture in female soccer players (Mandelbaum et al., 2005). The incidence and distribution of injuries seems to be specific to the level of soccer played (Bollars et al., 2014; Herrero, Salinero, & Del Coso, 2014), gender of the players (Tegnander et al., 2008) and the local climate (J. W. Orchard et al., 2013; Walden et al., 2011) therefore injury surveillance data used for a prevention program should report on a similar population to the target audience. The current study is the first to report on injuries in male professional soccer players in Australia and should provide important information on the focal regions of a prevention program, including a high incidence of knee, hamstrings and hip/groin injury. The incidence of ACL injuries should be monitored over a period of several years to establish whether the high incidence found in the current study represents elevated risk for this injury in the Australian context.

Neuromuscular and cardiovascular fatigue are risk factors for injury and can affect a player within a match as well as throughout the season. There is an increased risk of injury in the last 15 minutes of match play, presumably due to the effects of fatigue (Rahnama, Reilly, & Lees, 2002) and with increased match congestion (Bengtsson, Ekstrand, & Hagglund, 2013). There is a deficiency in information regarding late match fatigue and whether this is due to cardiovascular or neuromuscular fatigue. This would be a critical distinction if an injury prevention program was to target the underlying cause of late match fatigue. Significant changes of both muscle power and cardiovascular fatigue have been noted from the start of the regular season through to the end of the season (Ronnestad et al., 2011; Silva et al., 2011). It has been shown that players with less match time demonstrate a greater decline in sprint speed and leg strength throughout the season (Silva et al., 2011) indicating the value of match play to assist in acquiring and maintaining strength and fitness. This fact has implications for players returning from injury absences (Silva et al., 2011). The injury risk from premature fatigue is likely to be greater in players with lower levels of fitness and in those with greater involvement in high intensity activity such as frequent sprinting (Frisch et al., 2011).

One of the challenges faced by coaching and strength & conditioning staff is to balance player loads to maximise gains in fitness and strength without compromising skill gains or placing players at increased injury risk due to neuromuscular fatigue. Maximising strength and fitness by the conclusion of the pre-season is imperative as both parameters begin to decline once the regular season commences (Krustrup et al., 2011; Ronnestad et al., 2011). Ronnestad et al (2011) found an improvement in the maintenance of strength with in-season strength training performed once a week compared to once per fortnight (Krustrup et al., 2011) however the effect of increased strength training volume on injury risk was not assessed.

Implications of findings for medical staff

To minimise injury occurrence, vigilance is required from the medical team throughout the pre-season and regular season fixtures, with heightened vigilance at particular times throughout the season and subsequent to certain injuries. The current study showed an increased number of initial injuries during the 1st quarter of the season, while other studies have indicated a need for heightened vigilance due to increased injury risks around match scheduling congestion (Bengtsson et al., 2013; Dellal et al., 2013; Dupont et al., 2010). Both circumstances may relate to inadequate pre-season fitness and strength (Frisch et al., 2011), which should be the focus of pre-season training as well as in-season maintenance (Ronnestad et al., 2011). Additional monitoring may be advantageous for five weeks after a player returns from hip/groin injury to full participation, as the current study found an increased incidence of injury during this period. Frequent maintenance of strength and fitness during the recovery period as well as throughout the season would be advisable (Ronnestad et al., 2011) as there is a loss of strength without matchplay (Silva et al., 2011).

The complex decision making process involved in declaring a player recovered from injury and fit to play without restrictions could be assisted by objective data on sport-specific tasks. Screening data collected during the pre-season period can provide baseline values for muscular strength, power and agility as well as cardiovascular fitness. This baseline data can assist in determining if a player has returned to full capacity prior to their return to full training. This data can also assist in monitoring in-season fatigue, indicated by a rapid drop in performance. Reduced conditioning, strength and performance on return from an injury absence from a lack of game time (Silva et al., 2011) or during the season due to poor recovery after games will result in premature onset of fatigue, increasing the injury risk to the player (Frisch et al., 2011).

Design of a prevention program

The injury prevention model, proposed by Van Mechelen et al (1992) and later refined by Finch (2006), suggests that the steps to injury prevention must be followed in sequence to ensure valid results (see Appendix 2) (Krustrup et al., 2011). The study detailed here provides injury surveillance data for Australian professional soccer; from this data, injuries with the greatest impact on players and teams can be selected for further study. This injury selection should be based on the total number of missed games and the potential for injury prevention. Further data could then be gathered on the circumstances of each injury occurrence (Finch, 2006). Circumstances such as contact or non-contact, regulation play or foul play and game or training time elapsed could assist in determining the specific focus and target of any potential injury prevention programs or strategies (Maffulli, Longo, Gougoulias, et al., 2010).

The approach to evaluation of any prevention program requires consideration as to whether a competition-wide approach or a club-based approach is more appropriate. There are benefits to taking a whole-of-league approach, where the maximum number of participants would be involved in the study, generating a large volume of data in a relatively short period of time and improving generalisation to the population of participants in that sport. However, due to the number of involved parties, there is the potential for poor compliance due to difficulty in monitoring such a geographically diverse group of participants and data recorders.

Accordingly, a smaller scale approach to the implementation and assessment of an injury prevention program is often more feasible. This approach would involve only a proportion of the teams, as any untested prevention program is unlikely to be deemed to be mandatory by the governing body and all clubs are unlikely to nominate to trial a voluntary program. There is also the potential for different prevention programs to run concurrently at different clubs over the same season. This would increase the duration of the study to a number of seasons over several years as the researchers accrue sufficient data for analysis. This limited approach would allow closer monitoring of the prevention programs and data collectors, however it is important to apply the prevention program to more than one team as the results may be affected by one club's policies and decision making processes (Krustrup et al., 2011).

The injury prevention model requires relative stability of the conditions and variables that may affect injury rates, such as rules governing the game, field surfaces and salary cap restrictions. Rule changes can affect injury rates (Gabbett, 2005; Krustrup et al., 2011; Orchard & Seward, 2009) while surface changes may affect a specific injury or subset of injuries (Orchard et al., 1999). Another factor which may affect injury rates is the salary cap, a limit set for player salary expenses per club for one season. Salary cap increases may lead to an increase in the average age of players as clubs could afford established players with more playing experience. An older playing roster has been associated a greater risk of injury (Arnason et al., 2004) and will potentially affect injury rates. When these changes occur after baseline injury surveillance data is obtained and during the course of any prevention program, they create potentially erroneous explanations of changes in injury rates.

Continuing to study the injury prevention model will require preventative interventions to be trialled and evaluated, and the overcoming of various barriers to this process. All stakeholders should have some input into the selection of key areas for injury prevention strategy. The difficulty arises when programs need to be implemented to trial prevention strategies. At a professional level, it is unlikely that experimental prevention strategies will be mandatory. Rather, it is more likely that clubs could volunteer to participate in the program, reducing the sample numbers, leading to a longer period required for evaluation to obtain adequate statistical power. There are also compliance issues with any prevention program at a professional level when the trial program may be modified or ceased based on observations and expectations of club staff.

Injuries occurring in the pre-season period are a result of preparation for regular season games and should be considered in the same light as injuries in regular season training. Recording the pre-season period was not possible for the current study as most teams were still in the process of acquiring players and had not finalised their playing group until the commencement of the regular season. This was in part due to an overlap with finals games involving some newly recruited players currently playing in Australian state-based soccer teams. This is expected to be an ongoing issue for the Australian professional competition unless the state-based competitions were to align their regular season with the pre-season of the Hyundai A-League.

The most appropriate approach to the current situation would be to follow players over a number of A-League seasons. This will give better continuity of data however it could be expected to adversely affect drop-out rates. It would also be recommended to follow players for a period of time after the cessation of their team’s involvement in the competition as players may delay non-urgent surgery and rest for significant injuries until after the conclusion of their team’s participation in that season. The primary barrier to recording this data is the lack of formal or centralised training during the off-season and the lack of comprehensive medical coverage after the end of the competition season. Another barrier to off-season recording is the difficulty in defining injury when there are no scheduled fixtures, as noted by Orchard & Seward (2002).

To be maximally effective, data collection forms should maintain simplicity to enhance useability while enabling recording of sufficient detail to be useful. One method of enhancing use is to limit the number of options for each reporting category without compromising the detail obtained. This can be accomplished by amalgamating less common options that have identical impact on the outcome; for example, grouping all non-injury-related absences under one category. Where the absence involves some form of participation in soccer, such as national team duties, the absence should be categorised separately as it involves exposure to situations with known injury risk.

More comprehensive analysis would be possible with additional player demographic information, allowing sub-group analysis and calculation of injury risk for specific demographic characteristics. Arnason et al (2004) analysed injury risk for soccer players in Iceland based on body morphology, power and flexibility, joint stability, cardiovascular fitness and injury history. Conducting a similar study in Australia would allow analysis of similar variables as well as extrinsic risk factors such as weather conditions and their impact on injury risk. Information on weather conditions could easily and automatically be captured by an injury surveillance smartphone app without adding an additional reporting requirement for the team's data recorder. This information may assist in interpreting the contradictory findings of Orchard et al (2013) and Walden et al (2011) on the impact of climatic conditions on injury risk. It is noted that climate and weather are not synonymous, and it may be expected that temperature and humidity on the day of play will have a greater impact on injury rates than the average conditions of the previous decades.

Injury surveillance studies conducted at lower levels of soccer would allow prevention programs to be trialled with larger sample sizes and their effect evaluated for sub-elite populations. Injury prevention programs such as FIFA11 and FIFA11+ (see Appendix 3) have shown good results after implementation on a national-wide scale in Swiss amateur levels of soccer (Junge et al., 2011) and in female youth soccer teams ("The "11+" - FIFA.com," ; Steffen et al., 2013). However the same programs did not demonstrate a preventative effect in Italian amateur competition (Gatterer et al., 2012). One possible explanation is that the prevention program has a greater effect in low-skill amateur teams compared to high-skill amateur teams, as higher skilled teams have lower injury rates (Junge et al., 2002). Gatterer et al (2012) found that the FIFA 11+ injury prevention program had no effect on injury rates, but noted that injury rates decreased with increasing skill level in amateur teams and concluded that the injury rate is more dependent on skill level rather than the prevention program.

Future directions

Web-based data collection methods

Injury surveillance aims for accurate and complete data collection (Hagglund, Walden, Bahr, et al., 2005; Krustrup et al., 2011). Facilitating and streamlining this data collection with easy-to-use collection and submission forms should improve this process. Information recall accuracy diminishes with time elapsed and the amount of information required (Gabbe et al., 2003; Valuri et al., 2005). To optimise data accuracy, a collection method that is available in multiple formats on multiple devices would be ideal. This would allow a professional team's medical staff to record injury data in a timely fashion to minimise recall bias and inaccuracy (Gabbe et al., 2003; Valuri et al., 2005). Ensuring lay terminology is used and a simple input method would broaden the scope of individuals who could enter injury data, making it available to less technologically skilled individuals and non-medical support staff in addition to time-poor medical staff.

The development of a web-based data collection method, available on mobile or desktop devices, that was validated for use by non-medical individuals would extend the availability of injury surveillance to recreational level participants. Rather than waiting until returning to the office or home environment to record injury data, mobile versions of the collection method would be readily accessible at the field. Future research would be required to validate the use of any collection method and the reliability of interpretation of the injury definition and regional division of injured areas collected by this method. With a reliable and valid web-based solution, data could be collected from recreational to sub-elite level teams to contribute to a central database on injury trends and patterns.

The data collection app could perform two functions: it could collect large volumes of user-generated data on injury and automatically record weather-related data on recreational to sub-elite level footballers to enable analysis of injury risk relative to weather conditions and it could eventually be used to warn users of an increased injury risk due to the prevailing weather conditions.

There is conflicting information on injury risk and climate from Orchard et al (2013) and Walden et al (2011) and the acute effect of weather conditions on injury risk has not been established. A mobile application could automatically record weather conditions in the local area, providing important details for analysis of risk based on temperature, humidity, rainfall and other weather parameters.

In-season monitoring as a predictor of injury risk

Frisch et al (2011) analysed injury data based on pre-season screening results in order to determine potential injury predictors. This approach is helpful in contributing to the design of prevention programs although addressing the underlying injury predictors does not always correlate to reduced injury rates. Another approach would be to monitor key parameters during the season and use these values to assist in identifying those at risk of injury due to transient or gradually declining strength, conditioning or agility performances.

Research would need to focus on designing and validating in-season tests that will not contribute to injury risk by inducing fatigue but can be used as reliable and valid measures of elements of performance. Tests such as the Yo-Yo Intermittent Endurance Test Level 2 rely on inducing significant fatigue with repeated bouts of intense exercise to achieve a valid and reliable result (Silva et al., 2011). As fatigue is a risk factor for muscle and overall injury (Frisch et al., 2011; Rahnama et al., 2002), performance of this test during the season will potentially place players at greater risk of injury. Other tests are highly reliable and yield important information (Krustrup et al., 2011) but induce an unacceptable level of damage and functional impairment, making them impractical and ill-advised for in-season use. A suitable test would need to be objective enough to be useful but also be suitable for self-administration to enable its use for recreational and community-based players. Tests for professional and elite level players can utilise the club’s resources including equipment and medical staff and any additional services that may be required could be financed.

Conclusion

Injury prevention requires a multi-faceted approach to successfully reduce the injury risk to players. This study is the first published report of injury surveillance in professional soccer in Australia. It contributes to the geographical picture of injuries in professional soccer in regions around the world.

The primary challenge for injury surveillance is to select an appropriate definition of injury that can accurately portray the injury situation within the sport. In this study, a “time loss” definition was chosen, requiring that a player be restricted from full participation due to injury on the day after the incident.

The findings revealed the most commonly injured regions to be the knee, the hamstrings and the hip/groin and the regions associated with the longest average recovery time were the knee, ankle and foot. Interestingly 71% of players sustained at least one injury throughout the season, a proportion far exceeding what might be considered to be acceptable for a workplace. The player salary related cost of injury ranged from 6.6% to 20.8% of a club’s salary cap, amounting to $3.4 million across the league.

After an initial hip/groin injury, players were significantly more likely to sustain another injury within 5 weeks of their return to full participation and for the rest of the season. This information, coupled with the significant increase in initial injuries in the first quarter of the season, should assist the medical staff of a professional club by identifying periods when improved vigilance may be required.

Our injury data matched European (Arnason et al., 2004; Hagglund, Walden, & Ekstrand, 2005) and American (Agel et al., 2007) studies of the distribution of injuries around the body however the Australian training injuries to game injuries ratio was significantly different, with a lower proportion of training injuries seen. Some other comparisons were not possible due to the nature of the injury definition or return to sport definition, a problem which has also been identified by Hagglund et al (2005).

Finch (2006) suggests that the next stage of injury prevention is to establish the aetiology of injury and its mechanisms. This will allow the development of well-informed injury prevention programs which can then be tested by injury surveillance and comparison made to the original injury data.

Gathering injury data in sufficient detail without compromising the accuracy of data due to recall bias is one of the challenges facing sporting injury researchers at present. Further research on the use of mobile and web-based injury surveillance collection methods is warranted.

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APPENDIX

LIST OF APPENDICES

Appendix 1

As co-authors of the paper "Prospective epidemiological study of injuries in the Australian national soccer competition"

We confirm that **Peter Colagiuri** has made the following contributions:

- Conception and design of the research
- Analysis and interpretation of the findings
- Writing the paper and critical appraisal of the content

Signed...

Signed..

Appendix 2

Model stage	TRIPP	van Mechelen et al 4 stage approach [1]
1	Injury surveillance	Establish extent of the problem
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Develop preventive measures	Introduce preventive measures
4	"Ideal conditions"/scientific evaluation	Assess their effectiveness by repeating stage 1
5	Describe intervention context to inform implementation strategies	
6	Evaluate effectiveness of preventive measures in implementation context	

Fig. 1 The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention.

New framework for research leading to sports injury prevention as proposed by Finch. (Finch, 2006)

Appendix 3

STRUCTURE OF THE "11+"

The "11+" has three parts with a total of 15 exercises, which should be performed in the specified sequence at the start of each training session.

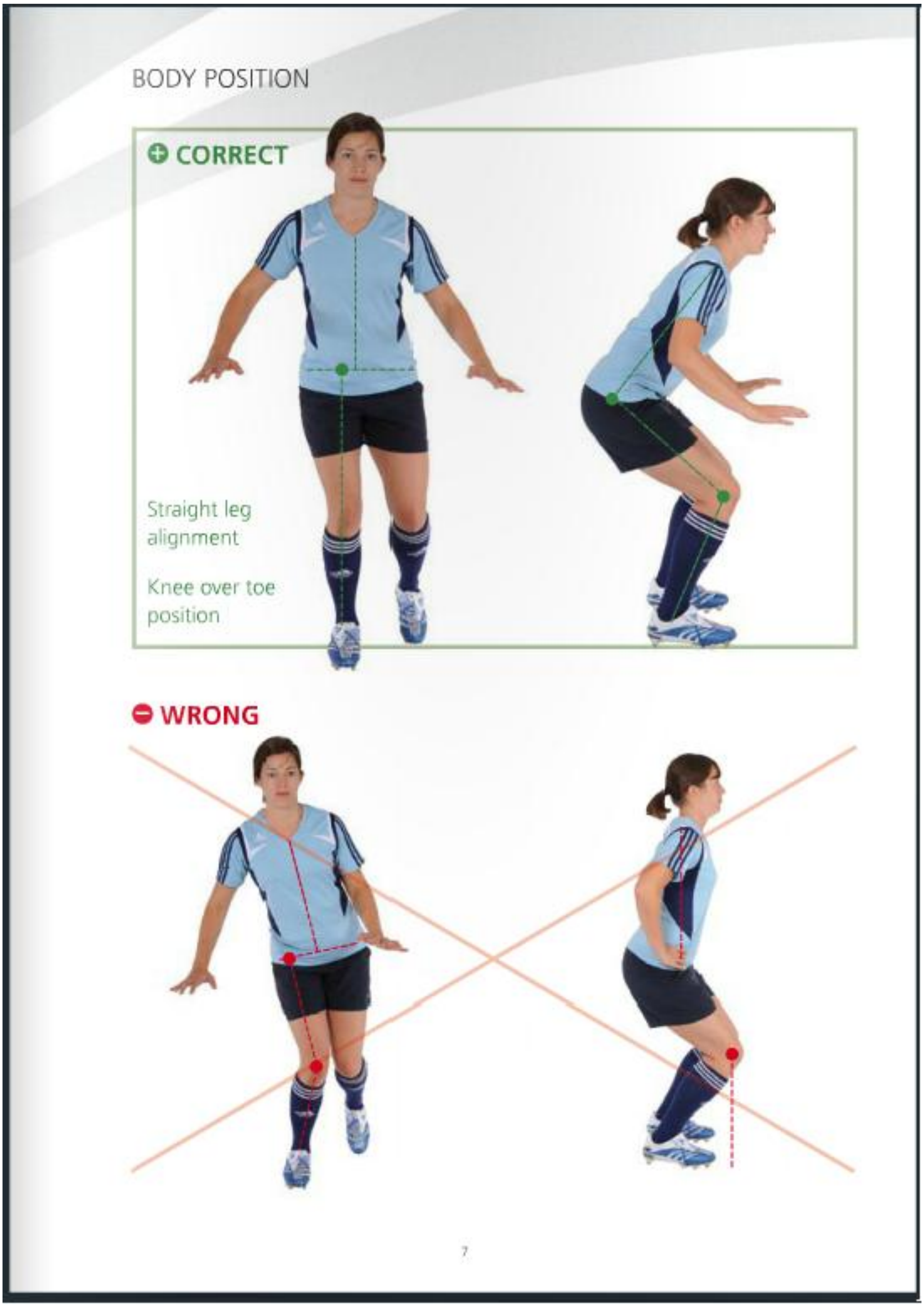
Part 1: running exercises at a slow speed combined with active stretching and controlled partner contacts;

Part 2: six sets of exercises focusing on core and leg strength, balance and plyo-metrics/ agility, each with three levels of increasing difficulty; and

Part 3: running exercises at moderate/high speed com-bined with planting/cutting movements.

A key point in the pro-gramme is to use the proper technique during all of the exercises. Pay full atten-tion to correct posture and good body control, includ-ing straight leg alignment, knee-over-toe position and soft landings.

6



Sample of pages from FIFA 11+ manual

From http://f-marc.com/11plus/manual/