Injuries in Professional Australian Soccer;

a League-Based Analysis of Injury Trends, Influences and Infrastructure.

By

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Certificate of Authorship and Originality of Thesis

I, Donna Lu, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abbreviations Symbols and Subunits

Symbol/Abbreviations	Word/Phrase
A-League	Australian League
FFA	Football Federation Australia
AFC	Asian Football Confederation
FIFA	Fédération Internationale de Football Association
UEFA	Union of European Football Associations
CONACACAF	Confederation of North, Central America and Caribbean Association Football
CONMEBOL	South American Football Confederation
CAF	Confederation of African Football
OFC	Oceania
F-MARC	FIFA Medical and Research Centre
PFA	Professional Footballers Australia
CBA	Collective Bargaining Agreement
MMS	Minimum Medical Standards
OSICS	Orchard Sports Injury Classification System
SMDCS	Sports Medicine Diagnostic Coding System
GPS	Global Positioning System
GLM	General Linear Model
GLMM	Generalised Linear Mixed Model
RR	Rate Ratio
ICC	Intraclass Correlation
CV	Coefficient of Variation
CI	Confidence Interval
h	Hour/s
=	Equals
≈	Approximately equal
+	plus
±	Plus or minus
%	Percent
α	Alpha
β	Beta
χ^2	Chi-Squared

Publications Resulting From this Thesis

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In review

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Lu, D., McCall, A., Jones, M., & Duffield, R. Variability of team-level injury underlying league-level injury rates in a professional soccer league. *Currently reviewed by the Legal Department of Football Federation Australia*

Lu, D., McCall, A., Jones, M., Steinweg, J., Gelis, L. & Duffield, R. The provision and infrastructure of medical care in professional Australian Professional Soccer Clubs. *Currently reviewed by the Legal Department of Football Federation Australia.*

Abstract

This thesis examines injury epidemiology, the impact of those injuries and the context of the injury epidemiology in the Australian professional soccer (association football) league (the A-League). To do this, data on injury, player-salary, team performance and provision and infrastructure of athlete care were collected from all A-League teams between seasons 2012/13 to 2017/18. The event of an injury and the characteristics were collected via a standardised injury surveillance system. For Study 1, the injury data was aggregated as a league and then by injury characteristics i.e. setting, mechanism, type and location. Generalised linear models (GLM) were used to model the data against seasons to report injury incidence rates (per 27 rounds) and trends over time. For Study 2, the injury data was aggregated by teams, and generalised linear mixed models (GLMM) were used to model the data against seasons to report injury incidence rates (per 27 rounds) and trends. Further, this analysis considered variations in team injury rates within a season and differences between teams across multiple seasons. For Study 3, the injury data was paired with player-salary and team performance costs of injury which were collated from confidential and publicly available data. Again, a GLM was used to analyse the trend of player-salary cost of A-League injuries and whilst a GLMM was used to assess the association between injury and team performance variables. For Study 4, the injury data was contextualised through a survey study where the head physiotherapist of each A-League team was asked to outline the provision and infrastructure of athlete care within the A-League.

The key findings from these studies were:

Study 1:

- The league-level (A-League) injury incidence rate ranged from 4.8 (95%CI:4.1–5.8) to 6.7 (95%CI:5.8–7.8) injuries per round per season and there were no significant differences between season 2012/13 to 2017/18 ($p<0.05$).
- Thigh injuries (23–36%), particularly hamstring injuries (54%–65%), were most common, with muscle/tendon injures the most common type (50–60% of total injuries/season). There were no significant differences between seasons within each injury type or location ($p>0.05$ and $p>0.05$, respectively).
- Regarding the setting of which injuries occur, training injuries decreased across the 6 seasons (exp(β) 0.59[95%CI:0.36–1.0]; $p = 0.04$).
- Although there was a higher proportion of non-contact injuries, both contact and non-contact injuries were not significantly different across the 6 seasons ($p > 0.05$).
- Mild severity injuries decreased (exp(β) 0.64 [95%CI:0.4–0.9];$p = 0.02$), whilst moderate severity injuries increased (exp(β)1.7 [95%CI:1.0–2.8];$p = 0.04$) in season 2017/18 compared to 2012/13. Severe injuries remained stable across the 6 seasons ($p>0.05$).

Study 2:

- Low variance (mean ± standard deviation = 34.1%±21.7) and poor to moderate reliability of between-season injury rate (ICC=0.319-0.831) supports the consistent stable injury trends at the league- and team-level injury rate.
- Team-level injury incidence rate ranged from 12.1 (10.1-14.5) to 18.2 (15.7-21.0) injuries per team per season, which significantly decreased in 2015/16 compared to 2012/13 (p=0.011).
- Joint/ligament injury rates significantly reduced in 2015/16 (p=0.001), which coincides with the significant reduction of injuries in the overall team-level injury rate. The model variance showed the reduction of Joint/ligament injuries was league-wide ($R^2m=0.23$; $R^2c=0.23$).

Study 3:

- Total league missed matches were significantly higher in season 2013/14 (55.1[50.7-59.9]; p<0.01) and 2014/15 (71.4 [66.4-76.8]; p<0.001) compared to 2012/13, without differences between other seasons. The significantly higher missed matches in 2014/15 were concomitant to the peak of player-salary cost which ranged between AUD $187,990 – AUD $332,680/team (p<0.01).
- Higher injuries rates were associated with additional goals conceded (p=0.007). Similarly, sum of missed matches was associated with more conceded goals and drawn matches (p<0.000).

Study 4:

- There were typically 1.6-1.9 physiotherapist per team tenured for 3.1±2.4 years and were postgraduate qualified (55-70%) with experience from other sports (70-91%). Additionally, there were 1.1-1.4 physicians, 1.1-1.3 massage therapists and 1.2-2.0 Exercise specialists each season ($p>0.05$).
- The Time Demands of practitioners did not differ between seasons ($p>0.05$), except for Exercise Specialists who increased by ≈30 h/week in 2015/16 compared to season 2010/11 ($p=0.014$).
- The provision of injury prevention programs was delivered daily as a whole squad over the 4 seasons ($p>0.05$). However, an increase in subgroup injury prevention on either a daily or several times/week existed ($\chi^2=0.041;p=0.005$). All teams completed preseason musculoskeletal screening in all seasons.

In summary, muscle/tendon injuries at the thigh, particularly at the hamstring, are of interest for stakeholders when developing or allocating resources to injury prevention. Competition organisers and medical staff should still be aware of the variation in less common injuries, though individual injury trend analysis should address such an issue. Key findings suggest interpretation of stable league- and team-level aggregated injury rates is accurate, which is supported by the low between-season injury rate variance. Nonetheless, injury prevention programs need to continue to focus on muscle/tendon and joint/ligament injuries at the hamstring and knee.

The league-wide reduction in injury rate in 2015/16 was mirrored by a trend for reduced joint/ligament injuries. The observed reduction was league-wide rather than a single team or a group of teams, suggesting most teams had exposure to the cause of the injury reduction. Although currently speculative, league-wide injury prevention strategy, such as a league-wide physical exercise programs, education and/or policy, may be plausible explanations. Such strategies require all levels of stakeholders (i.e. Competition organiser, clubs/ team officials and players) to be involved. Of interest to competition organisers and coaches, injury and missed matches are associated with goals conceded and matches drawn, though the magnitude of the association is small.

Finally, the findings suggest that injuries are relatively stable, and infrastructure of athlete care was similar despite more recent emphasis on injury prevention in the A-League between seasons 2012/13 to 2017/18. Competition organisers and clubs should be aware that having adequate provision and infrastructure of athlete care within teams may enable better control of injury rates. However, further reductions of injury require targeted injury prevention programs to the team and the individual player.

Chapter 1 : Introduction

1.1 Introduction

Professional soccer (association football) leagues can generate millions in revenue from jersey sales, tickets, sponsorships and broadcasting deals; ultimately resulting in the high financial value of professional players (Deloitte 2019). However, the most significant assets, i.e. the players, may not be profitable if they are unavailable to play, which may affect the success and competitiveness of teams (Parry & Drust 2006). The most common reason for player unavailability is injury, which poses issues for player welfare and raises critical concerns for sporting organisations (Arliani et al. 2014; Hägglund et al. 2013; Vann Jones, Breakey & Evans 2014). It is within the responsibility of a sporting organisation (e.g. national federations, governing bodies, leagues etc) to protect the image of the game, ensure financial sustainability of all licenced professional clubs and the welfare of all players (Ekstrand 2013; Vouillamoz 2016). As an attractive competition can yield higher revenue for the league, investment in injury reduction is imperative (Garcia-del-Barrio & Szymanski 2009).

Further, sporting organisations have the responsibility of upholding duty of care for athletes. Therefore, decisions imposed on clubs by sporting organisations should be made with consideration of player health and wellbeing; particularly, as acute and long-term health implications are possible. Given injury prevention research is commonly conducted in European soccer, the lack of systematic injury prevention research in Asia-Oceania has prompted calls for more injury prevention efforts within the Asian Football Confederation (Eirale, Farooq, et al. 2013). In Australia, the professional league (A-League) is operated by the national governing body; Football Federation Australia. The A-League is geographically isolated from other leagues and operates as a closed league system with a salary cap; which is advantageous in exploring the relationship of injury on trends, performance and infrastructure in a professional league. However, Australia is geographically big compared to European and other Asian countries, hence it is worthwhile to note the clubs, the state the club is based in and the seasons competed in the A-League (Table 1.1).

Table 1.1. List of A-League licenced Clubs, their locations and the seasons competed in the A-League (✓).

Club	*State*	*Seasons Played*							
		2010-11	*2011-12*	*2012-13*	*2013-14*	*2014-15*	*2015-16*	*2016-17*	*2017-18*
Adelaide United FC	*South Australia*	✓	✓	✓	✓	✓	✓	✓	✓
Brisbane Roar FC	*Queensland*	✓	✓	✓	✓	✓	✓	✓	✓
Central Coast Mariners FC	*New South Wales*	✓	✓	✓	✓	✓	✓	✓	✓
Gold Coast United FC	*Queensland*	✓	✓						
Melbourne City FC (Formally Melbourne Heart FC)	*Victoria*	✓	✓	✓	✓	✓	✓	✓	✓
Melbourne Victory FC	*Victoria*	✓	✓	✓	✓	✓	✓	✓	✓
Newcastle Jets FC	*New South Wales*	✓	✓	✓	✓	✓	✓	✓	✓
North Queensland Fury FC	*Queensland*	✓							
Perth Glory FC	*Western Australia*	✓	✓	✓	✓	✓	✓	✓	✓
Sydney FC	*New South Wales*	✓	✓	✓	✓	✓	✓	✓	✓
Wellington Phoenix FC	*Wellington, New Zealand*	✓	✓	✓	✓	✓	✓	✓	✓
Western Sydney Wanderers FC	*New South Wales*			✓	✓	✓	✓	✓	✓

1.2 Injuries in professional soccer

Reducing injuries requires a systematic process of initially understanding the injury situation via injury epidemiology research (van Mechelen, Hlobil & Kemper 1992). An injury incidence rate is a simple calculation commonly used to report a relative injury occurrence based on the number of injuries that occur over a period of time (Hopkins et al. 2007). In professional soccer leagues, such as, the English Premier League, Eliteserien, La Liga, Allsvenskan, and Persian Gulf Pro League, it has been reported that injury incidence is typically between 2 – 17 injuries/ 1000 exposure hours (Bayne et al. 2018; Bjørneboe, Bahr & Andersen 2014; Dauty & Collon 2011; Hassabi et al. 2010; Jones et al. 2019). Further, the most common soccer injuries occur in the lower body at the thigh and are of muscle/tendon and joint/ligament type (Fünten et al. 2014; Shalaj et al. 2016). Whilst these reports describe the injury situation at a given moment in time; rates are reported from a range of teams and leagues under varying circumstances making comparisons difficult. Additionally, club and league-based injury rates are often reported, limiting the ability to identify relevant trends and associated causes or consequences (Robertson 2007). Accordingly, injury rates can identify the prevalence and prioritise the importance of injury prevention focus. However, injury trend analyses add further context to the longitudinal nature of injury development and success of policy or interventions on injury rates.

Injury trend analyses can differentiate natural fluctuations from meaningful changes in injury incidence rates (de Freitas Guina Fachina et al. 2013; Hagglund et al. 2005; Noya Salces, Gómez-Carmona, et al. 2014). Of the few multi-team, multi-season studies, the injury trend in professional soccer is reported to have remained stable (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011; Gouttebarge & Kerkhoffs 2017). Whilst the data represent Leagues in Europe and Japan, limited injury research is reported within the A-League context. In Australia, Gouttebarge & Kerkhoffs (2017) reported reduced injury incidence from 202 injuries in the season 2010/11 to 162 injuries in 2012/13. Similarly, missed matches due to injury also decreased from 1110 in 2010/11 to 542 in 2012/13. However, the aforementioned study was limited to purely an injury count without relative exposure and was delimited to only hamstring, knee, ankle, and groin injuries. Additionally, the injury trend is outdated and requires a comprehensive updated evaluation for the A-League.

Although injury epidemiology is needed, there are methodological issues that make a comparison of data between leagues fraught with error. Injury epidemiological data is typically collected at the individual level and aggregated into a group. Inherited issues of aggregation at different levels of analysis beckons questions of validity that only two studies have investigated (Morgenstern 2014). Ekstrand et al. 2013, reported 60% explained variance by accounting for historically successful clubs when modelling injury trend in 23 UEFA teams. Bjørneboe, Bahr & Andersen (2014) accounted for inter-team variation and clustering effects, reporting a reduced annual rate of 0.92 (95%CI:-0.11-1.95, p=0.083) from 1.06 acute match injuries/1000 h (95%CI: 0.40–1.73). Of concern, no following league-level injury epidemiology studies have considered the relationship or influence of team-based injury data when interpreting the league-level injury trends. Such insight is required for league-level organisations to better understand the need and use of policy driven interventions to assist and improve player health and competition viability.

1.3 The impact of soccer injuries

Soccer injuries have a multifaceted impact on professional leagues, which can be classified as financial, performance or health costs (Ekstrand 2013). Recent publications have realised that the injury situation within soccer leagues is not best described through injury incidence alone (Bahr, Clarsen & Ekstrand 2018). Accordingly, understanding the cost of injuries may prompt engagement of developing, enforcing or resourcing injury prevention programs from the national governing body. Furthermore, understanding the cost of injury may highlight issues of importance that influence injury prevention implementation by key stakeholders. From an A-League perspective, Gouttebarge & Kerkhoffs (2017) reported the financial injury cost to have peaked at AUD $6 million in Season 2010/11, before a continuous decrease to AUD$3 million within 2 seasons following the implementation of the Minimum Medical Standards (MMS) in 2011/12. Although this financial injury cost is small compared to UEFA Champions League (UCL), where injuries amount to €20 million per season per 25 player squad (Ekstrand 2016), it is worth mentioning the differences in competition format. European and most leagues around the world have an open league system (i.e. promotion and relegation and no salary cap) making it difficult to compare the results to a closed system and salary-capped league in Australia. Therefore, further analysis of player-salary cost for Australian soccer players is warranted in order to further understand the current context.

A common concern of player unavailability is the presumed negative effect on team on-pitch performance (Hoppe et al. 2015). More specifically, less player unavailability potentially due to lower injury incidence has a positive association with end-of-season league ladder ranking and physical match outputs in the French, Qatari, Icelandic top tier leagues, and the UEFA Champions League (Arnason et al. 2004a; Carling, McCall, et al. 2015; Eirale, Tol, et al. 2013; Ekstrand et al. 2018). Further in the Qatari professional league, Eirale et al. (2013) reported lower injury rates were positively correlated with team ranking ($r=0.929$, $p=0.003$), more games won ($r=0.883$, $p=0.008$), more goals scored ($r=0.893$, $p=0.007$), greater goal difference ($r=0.821$, $p=0.003$) and total points ($r=0.929$, $p=0.003$). A limitation of the Qatari League study is the use of univariate analysis using a single seasons worth of data. A multi-season analysis of injuries and team performance relationship to increase the reliability of the associations is necessary. Further, the relationship between injury rates and team performance remains unknown in the A-League.

1.4 Provision and infrastructure of soccer player care

Important methods to prevent and support player injuries relates to the provision of injury reducing practices and the team officials i.e. coaching or medical staff (Buchheit et al. 2019; Reid, Stewart & Thorne 2004). For example, limited research regarding provision and infrastructure of athlete care in soccer suggests European clubs appoint ≈2.9 doctors and 5.2 physiotherapists per Premier League club (Malcolm, Scott-Bell & Waddington 2017). However, a semi-structured survey study of retired professional soccer players reported the perception that inadequate resources existed in clubs for injury prevention (Drawer & Fuller et al. 2002). In the only previous A-League injury epidemiology study, Gouttebarge & Kerkhoffs (2017) speculated the injury reductions observed after 2010/11 may have been due to the implementation of the A-League MMS. The A-League MMS came into effect in the

2011/12 season and entails a series of principles regarding programs, resources, qualification and medical rights that ensure players have access to adequate athlete management and care (Professional Footballers Australia 2015). Despite suggestion that the MMS may have reduced league injury rates, the provision and infrastructure for athlete care has yet to be intensely investigated at a league-wide level. Although the current state of literature suggest that provision and infrastructure of athlete care is important, few previous studies have described in detail this infrastructure, or how it has changed over time within a league (Gouttebarge & Kerkhoffs 2017; Vouillamoz 2016).

1.5 Thesis Aims

Given the importance of effectively reducing injuries from an Australian A-League perspective, this thesis aims to:

1. Determine the incidence of injuries and injury characteristics in the A-League and analyse the trend of injuries over a 6-season period (Study 1).
2. Examine the variability in league- and team-based injury rates in the A-League over 6 seasons (Study 2)
3. Examine the financial and performance cost of injuries in the A-League over 6 seasons (Study 3).
4. Profile and identify changes of the provision and infrastructure of medical care in professional A-League soccer clubs over a 6-year period (Study 4).

1.6 Significance of Thesis

Injuries have a multi-level impact on professional soccer players, teams and competitions. The extent of the injury-induced impact places emphasis on the importance of reducing injuries. League-based injury data may be novel and advantageous in removing bias and confounding factors such as different training programs, schedules and coaching styles of individual teams (Ekstrand et al. 2018; Meeuwisse 1994). However, it is possible that the shortcoming of analysing league-level data is the aggregation bias that may arise by not reflecting the individual team variability (increases or decreases per season) (Schwartz 1994). Regardless, in the present thesis, trends from aggregated injury data at the league-level can inform league policy and practice to aid club-level development of injury prevention.

Stable injury trends from multiple leagues in recent research demonstrate unknown effectiveness of a plethora of proposed injury prevention programs (Ekstrand et al. 2011; Aoki et al. 2012; Gouttebarge et al. 2017). Such trends allow the exploration of possible associated events, which are yet to be explored from a league-level perspective. Additionally, the impact of the injuries from financial and performance perspectives can further describe the effects of injury; though previous research has reported mixed findings on the association between performance and injury in professional soccer (Carling et al., 2015; Eirale et al. 2013; Ekstrand et al. 2013). In Australia, the injury situation is relatively unknown compared to European soccer leagues, hence injury epidemiology adopting standardised injury surveillance and reporting methods is required.

Understanding the characteristics of the injury problem in Australian professional club soccer, can improve the decision-making process for allocation of resources for prevention protocols and further research. In Australian professional soccer, only one study has published league-based injury data. Gouttebarge & Kerkhoffs (2017) reported stable injuries between 2008/09 to 2012/13 seasons with the exception of spike in season 2010/11; though no league-based injury data exists since this publication. The previously mentioned study suggested that the mandatory A-League MMS introduced as part of a Collective Bargaining Agreement (CBA) between the competitions governing body, FFA, and Professional Footballers Australia (PFA), may have had an effect on injuries. Such speculation is supported by the perception of inadequate injury prevention resources and support prior to acute and chronic injuries from active and retired English soccer players (Drawer & Fuller 2002). Therefore, the significance of the present thesis is due to the comprehensive investigation of injuries and the context of injuries specifically in the Australian professional soccer league from a league-wide perspective.

1.6 Limitations

Several limitations are present in this course of studies completed as part of this thesis, including;

- The definition of injury used in these studies (based on a long-term organisational definition) require a medical event resulting in a missed *official* A-League match. Such an injury definition may underestimate the number of medical events not resulting in a missed *official* A-League match. That is, the medical event results in time-loss and no missed match or a persisting medical event without any time-loss.

- The injury surveillance system in used during this period reported the event of an injury only if it occurred within the A-League season (excluding injuries sustained in off-season, preseason and during the finals series i.e. quarter-, semi- and grand- final).
- Player-salary cost of injury was calculated using the A-League salary-cap, matches missed and available players. Ongoing medical treatment, rehabilitation and insurance costs were not considered in the calculation of financial cost of injuries.
- The provision and infrastructure of athlete care in the A-League are from the perspective of the Head Physiotherapist. Other perspectives from relevant stakeholders e.g. players, physician, coach or exercise professional, were not considered. If team officials work in silos, assumptions are dependent on the relationships with team official, understanding of the roles and responsibilities of other team officials, and proximity to the club environment.

1.7 Delimitations

Several known delimitations are present in this sequence of studies, including;

- Comparison of injury data is made only to male elite level team sports due to the similar environment.
- All A-League teams were under the same competition and medical regulations including a salary-cap, no promotion and relegation and MMS.
- All A-League teams were exposed to the same competition format and number of rounds; however, exposure in hours was not collected and therefore count data was comparable between seasons.

- The performance cost of injury was delimited to the effect on teams across the league as opposed to individual player's physical, technical and tactical performance. Additionally, team physical, tactical or technical performance was not investigated.
- Injury data was collected using a standardised injury surveillance system implemented by FFA as part of the A-League MMS. The reliability and validity of injury data was managed via monitoring and engagement with the physiotherapists who entered data by the FFA compliance managers and injury surveillance officer. As injury surveillance was mandatory for all A-League clubs, a notice of breach and financial repercussions were in place if clubs did not comply.
- All injury data was recorded by a qualified physiotherapist ensuring the accuracy of diagnosing injury.

Chapter 2 : Literature Review

2.1 Overview

The influence of injuries on the success and competitiveness of teams, combined with adverse effects on player welfare, raises concern for sporting organisations (Arliani et al. 2014; Hägglund et al. 2013; Vann Jones, Breakey & Evans 2014). Sporting organisations have the responsibility to protect the welfare of players, image of the game and ensure financial sustainability of all licenced professional clubs. Investment into effective injury prevention strategies is imperative for national sporting bodies; however, professional league-wide strategies to injury reductions remains unreported (Ekstrand 2013; Vouillamoz 2016). The lack of reported sporting organisational and league-wide involvement in injury prevention may be due to the superficial reporting or club-specific nature of injury research. Although competition performance is the responsibility of the clubs, medical policy imposed on clubs by national bodies should be undertaken in the interest of player and club performance, as attractive competition can yield continuous revenue for the league (Garcia-del-Barrio & Szymanski 2009).

2.2 Literature Review Methods

The articles referred to in this review were located via internet searches on scholarly database platforms, particulalry PubMed, Google Scholar, Researchgate. The keyword terms ‘soccer/football injury*’, “Team sport injury prevention”, “soccer/football sport injury prevention”, “injury Surveillance”, “injury prevention”, ‘football injury prevalence’, were used to in a Boolean search for peer-reviewed articles. These articles (n=3077) were screened by abstracts and excluded if it did not examine a team sport of similar movement demands (i.e. intermittent running, tackling, jumping), unless explicit relevance was stated.

Additionlly, the terms “A-League”, “Salary Cap”, “Footbal Federation Australia”, ‘Football/Soccer Medical Reguations” “Professional Footballers Australia”, “FIFA-, UEFA, The FA-, AFC-, CONACACAF-, CONMEBOL-, CAF- , OFC - medical”. Inclusion criteria required papers that addressed injury surveillance, provision and infrastructure of athlete care in team sports the current injury situation of senior male professional football. Accordingly, 85 articles were included in this literature review (a schematic outline is presented in Figure 2.1).

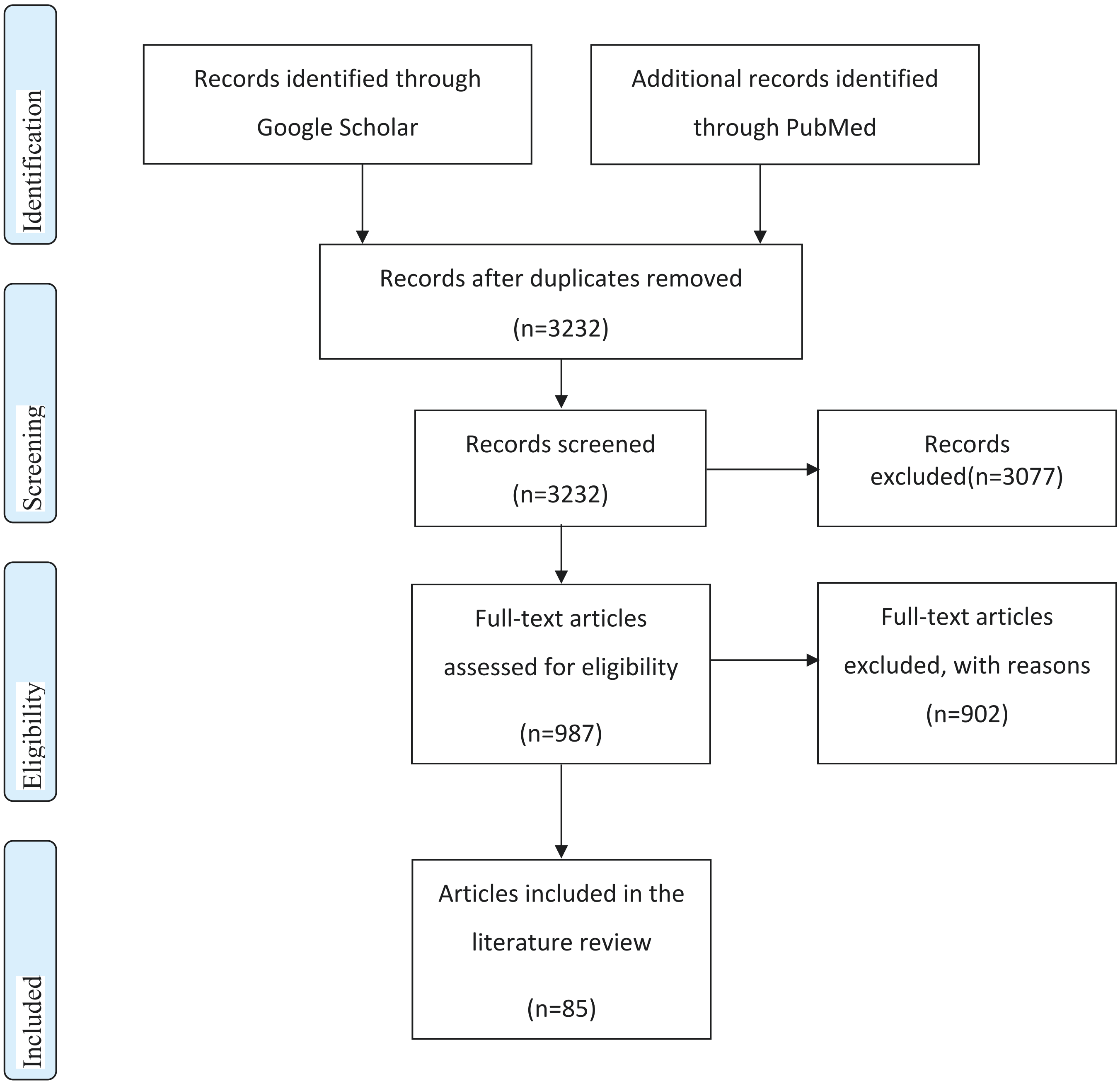

Figure 2.1. Schematic outline of literature search process and exclusion criteria for the current literature review (Moher et al. 2009).

2.3 The Professional Australian Soccer League

To develop feasible prevention strategies, contextual understanding of the professional soccer environment is necessary. The A-League is Australia's top-level professional league which formed in 2005 out of the previous guise of the National Soccer League. The A-League is governed by the Australian soccer sporting body, Football Federation Australia (FFA) which is a member of the Asian Football Confederation (AFC). To date, there is little understanding of the injury situation in the AFC; thus, calls exist for more injury epidemiology and standardised surveillance systems from Asian competitions (Eirale et al. 2017).

The A-League competition consists of 27 rounds per season with 9-11 clubs licensed over the last 14 continuous years of the current A-League. The A-League overlaps two other competitions in which A-League teams compete. Typically, A-League matches are scheduled at the end of the week (Friday to Sunday) and the season is played from October to April. The A-League season commences during the Football Federation Australia (FFA) Cup final rounds. FFA cup is a domestic competition featuring both top and lower-tier teams apart of the Australia leagues system. Additionally, selected A-League teams compete in the A-League simultaneously to the AFC Champions League. The AFC Champions League is an annual continental competition during and beyond the conclusion of the A-League season. Up to three teams can qualify for the AFC Champions league – the A-League grand finalist, premiers, runner-up finalist and/or highest-ranking team (conditional entry). Participation in either of these overlapping competitions results in a two-match week.

Understanding the structure of the A-League can provide further understandings on the limitations of the presented findings. The following will elaborate on the distinguishing factors on the A-League and by virtue, highlight the need to investigate injuries in Australian Soccer. Firstly, the A-League is a closed competition which refers to a competition where there are a fixed number of teams that play from season to season with occasional expansion or removal or teams. Such a competition system involves revenue sharing between teams and implements a salary cap. The A-League adopts a closed competition format similarly to the Major Soccer League (U.S soccer) and the Canadian Soccer League (CSL). Conversely, an open competition system refers to leagues that allow teams to be promoted or relegated to major or minor leagues. The mobility of teams between leagues places added value on players, allowing financially wealthy teams to dominant the competition. Examples of open competition soccer leagues include the English Premier League (England), La Liga (Spain), Series A (Italy), Ligue 1 (France), and Bundesliga (Germany). Although most professional soccer leagues are open leagues, the advantage of studying the A-League is relative stability amongst teams, thus creating fairness so that all teams theoretically have the opportunity to win the premiership.

Secondly, Professional Footballers Australia (PFA) on behalf of the players, secured a five-year Collective Bargaining Agreement (CBA) with FFA on behalf of itself and the A-League clubs. The CBA was first implemented to ensure players receive a fair share of game revenue and have minimum wage entitlements, protections from arbitrary dismissal, freedom of movement and a low-cost disputes resolution procedure. Under the fair share of game revenue, a salary cap was negotiated and fixed in the CBA. The A-League salary cap places a limit on the amount a team can pay players' wages within a team. From 2020, the A-League features ten Australian teams and one New Zealand team. Each team is permitted a roster of 20-23 players under the salary cap. Exemptions are made for designated, marquee, home-grown and loyal players. Fair wages as a result of the salary cap may reduce the impact on the players market by preventing the escalation of player salaries. However, competition imbalances leading to the dominance of a few clubs and potentially creating boring competition may reduce the fairness (Dietl et al. 2012; Késenne 2000). That said, if an A-League player becomes injured, financial stress can result for both the player, club and league. Therefore, understanding the financial cost of injuries in the A-League is just as crucial as the injuries themselves.

Amongst other CBAs, the A-League implemented a Minimum Medical Standard (MMS) after the 2010/11 season. The MMS was introduced as an effort to reduce injuries and financial cost savings in A-League clubs after an increasing A-League injury trend was reported in the 3rd edition of the PFA Injury Report (PFA 2009). The MMS originally had seven key aspects - Medical testing, Club Physician, Club trainers, Club Physiotherapists, Player Medical Records, Player's right to second opinion and Player's right to a surgeon of their choice. Up until Season 2017/18, there have been 5 revisions of the MMS of which the original aspects are outlined, and changes throughout the versions are listed in Table 2.1. Of note, FFA injury surveillance became mandatory from 2016 providing opportunity to review the injury situations and evaluate current practices. It is worth noting that the A-League MMS is comparable to the MMS implemented by UEFA to all their member federations and financially assisted by European Championship revenue through the UEFA HatTrick program. Additionally, the A-League MMS can also compare to another Australian example in the Australian Football League (Australian Rules Football) which mirror a closed competition format with an imposed salary cap. However, despite speculation from Gouttebarge & Kerkhoffs (2017) that the MMS could be influential on injury rates, neither of these previously mentioned MMSs have been investigated on their effects on player health and safety.

Table 2.1. Changes in the A-League Minimum Medical Standards.

	Version 2 – 2013	Version 3 – 2013	Version 4 – 2014	Version 5 – 2016	Version 6 – 2017
Medical Testing	Complete Medical Assessment	No change	No change	7 Day submission of medical assessment period to FFA Anterior cruciate ligament screening and injury prevention program must be evidence based and industry accepted. 12 – lead- resting Electrocardiography	Added Clinical Cardiovascular examination Echocardiogram every 2 years
Club Doctors	Certified by the Australasia College of Sports Physicians or Sports Doctors Australia Different home and away team doctor in an A-League match. Available ambulance at all matches	No change	Defined Club Doctors Role	Specific wording that Doctor is an integral part of the club Doctor decision on player health cannot be overruled by technical staff Must have minimum qualifications	No changes
Club Trainers	Sports Trainer Level 2 from SMA or tertiary qualification in S&C.	No change	No change	Must have minimum qualifications	No changes
Club Physiotherapist	Available to players before, during and after all training and matches.	No change	No change	Must have minimum qualifications	No change
Player Medical Records	Keep accurate records of injuries, illnesses, physical complaints, diagnostic tests, medical advice and treatment.	No change	No change	No change	No change

FFA Sports Supplements and Medication Guidelines		Added Medication Guidelines	No change	No change	No change
FFA Concussion Guidelines	Keep accurate records of injuries, illnesses, physical complaints, diagnostic tests, medical advice and treatment.	No change	No change	No change	No change
Continuous Education and Ongoing Improvement				Added component Added Medical Workshop Added Compulsory Injury Surveillance	No change

As the national body of soccer in Australia and organiser of the A-League, FFA has duty of care over licenced A-League players. Such responsibility is to reduce injuries and their ensuing financial and performance costs. It is important to understand injuries and their costs from an organisational perspective. Current efforts, in the form of policy, have been implemented to reduce injury, and whilst other sporting organisations also implement sport-specific MMSs, no previous study has investigated the effect of league-wide prevention. Moreover, the A-League's circumstances in a closed competition and limited to a salary cap is ideal to investigate injuries, the ensuing impacts and the athlete care environment.

2.4 Operational Definitions

Prior to discussing the many dimensions of injury, the relevant terminology should be defined to avoid confusion. For the purposes of this literature review, definitions for injury terminology will adopt definitions proposed in the consensus statement by FIFA Medical and Research Centre (F-MARC) (Fuller et al. 2006). Although a full list of terms and definitions can be found in the mentioned consensus statement, Table 2.2 lists the common and relevant terms. It should be noted that the consensus statement definition differs from the injury definition in the existing FFA injury surveillance, the A-League injury definition is *"any physical complaint requiring medical attention resulting in a missed A-League match"*. It should be noted the A-League definition of injury pre-dates the Fuller et al. (2006) definition and has been maintained for consistency of data reporting. The following section will discuss issues related to injury definition and the effect of definition discrepancies.

Table 2.2. Definitions of injury used in this document (Fuller et al. 2006).

Term	Definition
Injury	"Any physical complaint sustained by a player that results from a soccer match or soccer training, irrespective of the need for medical attention or time loss from football activities."
Medical Injury	An injury resulting in a player receiving medical attention regardless of time-loss.
Time-Loss Injury	"An injury that results in a player being unable to take a full part in future football training or match play"

2.5 Injury Epidemiology and Methodological Issues

Injury epidemiology is the study of characterisation of injury occurrence as described by frequency, prevalence or trends (Morgenstern 1995). Investigating injury epidemiology can lead to identifying injury risk factors, and the effect of those factors, as well as evaluation of injury prevention strategies and programs (van Mechelen, Hlobil & Kemper 1992). Thus, investigating the A-League injury epidemiology is imperative for understanding and to reduce injuries. However, when conducting injury surveillance and reporting on injury epidemiology it is important to understand the methodological issues involved. Discrepancies in injury definition, injury characteristics classifications and calculation can lead to limitations. Further, injury epidemiology studies adopt an ecological study design where by individual data is aggregated into a group as the unit of analysis (Schwartz 1994). Such a method is advantageous from the low frequency of injuries from an individual, though may lead to inappropriate application of findings (Piantadosi, Byar & Green 1988). The following section will address the sports injury epidemiology related issues with specific reference to soccer examples where the literature permits.

2.5.1 Injury definition and calculation of injury incidence

Defining injury is a fundamental aspect of injury prevention research and depends entirely on the question of interest (Best & Shrier 2007). Discrepancies in injury definitions can directly impact on the reported rates and trends (van Mechelen, Hlobil & Kemper 1992). Addressing the injury definitions, the Fuller et al. (2006) soccer-specific consensus statement addresses the nuances of injury definition and methods of calculating injury rate. More recently, a consensus statement on the injury epidemiology methodology for sport was released by the International Olympic Committee Injury Group (Bahr et al. 2020). This statement highlights the importance of reporting comparable injury epidemiology, particularly for understanding between-sport comparisons when funds are distributed between sports. More specific to Australian soccer injury epidemiology, Gouttebarge & Kerkhoffs (2017) reported league injury incidence as a count of 202 injuries in the 2010/11 HAL season. Hence, a current injury incidence expressed relative to exposure is necessary for the Australian professional soccer league to conform to international expectations. A limitation of reporting a count is the inability to compare between leagues and season due to variability in exposure between seasons and clubs. Sports and soccer specific consensus on injury epidemiology methods and reporting currently suggest reporting injury as an injury incidence rate per 1000 hours of exposure (Bahr et al. 2020; Fuller et al. 2006). However, practical considerations are required as collecting match and training exposure is time consuming, particularly when teams typically consist of approximately 25 players that need to be monitored individually. In circumstances where teams do not have the resources for individual exposure monitoring, calculation of team-based exposure is recommended (Ekstrand, Hagglund & Walden 2011; Fuller et al. 2006). However, team-based exposure can under- or overestimate exposure, given players do not always complete a full training session (Brooks & Fuller 2006; Fuller et al. 2006). Future injury epidemiology should consider standardised recording, calculations and reporting styles to allow for comparison. Despite such suggestions, arguably due to the distinguishing factors of the A-League, it may be more intuitive to resume current methods and compare within the same league over time.

There are many ways of reporting injury; however, injury incidence rate remains the most popular method, despite inconsistencies of reporting in previous literature (Brooks & Fuller 2006; Ekstrand, Hagglund & Walden 2011; Fuller et al. 2006). In professional soccer, injury epidemiological studies are typically reported in single teams, with an injury incidence of 8.3– 16.5 injuries/ 1000 exposure hours (Hassabi et al. 2010; Larruskain et al. 2018; Muaidi 2019; Reis et al. 2015). Aggregation of team data shows a time-loss injury incidence rate between 2.2-9.4 injuries / 1000 exposure hours, with the rate of match injuries (24.6-22.7 injuries/ 1000 hours of match exposure being greater than in training (0.9-2.1 injuries/ 1000 hours of training exposure) (Table 2.3). A major limitation of reporting individual club or data from only a few teams is the lack of transfer the information has to a league. Such differences may exist due to differences in elected leadership, training load, periodisation, recovery and injury prevention methods (Ekstrand et al. 2018; Lu et al. 2017; McCall et al. 2014). That is, despite similar goals of winning a competition, the processes in doing so are vastly different (Busso et al. 2002; Castagna et al. 2011; Fanchini et al. 2015; Høigaard, Jones & Peters 2008). Differences exist in coaching styles, training loads and types, nutrition, experience, medical services and scheduling. Such idiosyncrasies between teams highlight the importance of conducting injury surveillance across a league to understand normative injury incidence rates, as well as the underlying variation at team-level.

Table 2.3. Injury Incidence of multi-team professional soccer injury epidemiology.

Author/s	League	Surveillance Period	Teams (n)	Overall Injury Incidence (/1000h)	Match Injury Incidence (1000/h)	Training Injury Incidence (/1000h)
Arnason et al. (1996)	Icelandic Premier League	1991	5	12.4	34.8	5.9
Arnason, Engebretsen & Bahr (2005)	Icelandic Premier League & First Division	2000	8	6.6	26.0	1.9
Bayne et al. (2018)	South African Premier Soccer League	2015/16	2	2.2	24.8	0.9
Bjørneboe, Bahr & Andersen (2014)	Norwegian Premier League	2002-2007	14 – acute injuries only		15.9	1.9
Ekstrand, Hagglund & Walden (2011)	UEFA Clubs	2001-2008	23	8.0	27.5	4.1
Hägglund, Waldén & Ekstrand (2003)	Swedish Premier league	1982 and 2001	1982= 12; 2001=14	1982= 8.3; 2001=7.8	1982= 20.6; 2001=25.9	1982= 4.6; 2001=5.2
Hägglund, Waldén & Ekstrand (2005)	Danish Super League	2001 – (spring season only)	8	14.4	28.2	11.8
Jones et al. (2019)	English Premier League & National Conference	2015/16	10	9.1	24.3	6.8
Lee et al. (2014)	Hong Kong Premier League	2010/11	7	7.4	61.1	3.4
Noya Salces, Gómez-Carmona, et al. (2014)	Spanish La Liga	2008/09	16	5.7	43.5	3.6
Noya Salces, Gomez-Carmona, et al. (2014)	Spanish Division 2	2008/09	11	5.5	38.8	3.8
Stubbe et al. (2015)	Dutch Premier Soccer League	2009/10	8	6.2	32.8	2.8

From a sports organisation perspective, epidemiological studies across a league can inform the state of the injury issue and provide a baseline for comparison to other leagues or future seasons (Bahr, Kannus & Van Mechelen 2003). League injury epidemiology data is often collected either at the individual or team level and aggregated into a sum or mean for the league. In professional soccer leagues, the injury incidence is typically ≈7.1 injuries/1000 hours of playing exposure and match injuries are greater than training injuries (Table 2.3). Of note, there are only two league-wide injury epidemiology studies adopting a time-loss injury definition which come from a European league (Bjørneboe, Bahr & Andersen 2014; Hägglund, Waldén & Ekstrand 2003). The clear lack of Asian region injury epidemiology makes it difficult to deduce meaningful conclusions for Asian leagues such as the A-League. However, the use of injury incidence rates is relatively superficial as they cannot suggest the behaviour of injury trends that may be more information for sports organisers and coaches.

Seasonal soccer injury trends can provide context to the natural fluctuation and identify meaningful differences. In the literature, two league-wide longitudinal injury epidemiology studies have been published with a time-loss injury definition, whilst another two have published using a match-loss injury definition. In a time-loss injury epidemiology in Norwegian premier league, Bjørneboe, Bahr & Andersen (2014) reported a 1.06 acute match injuries/1000 h (95%CI: 0.40–1.73) increase over 6 consecutive seasons (2002-2007). Additionally, in the Swedish premier league, the season in 1982 was compared to the 2001 season. Hägglund, Waldén & Ekstrand (2003) reported no differences between injury incidence or severity ($p>0.05$ and $p>0.05$, respectively). A stable injury trend was also reported from 15 seasons (1993–2007 seasons) of the J-League, with match-loss injury incidence rate stable at 21.7 injuries/1000 exposure hours ($p = 0.118$) (Aoki et al. 2012). Comparably, Gouttebarge & Kerkhoffs (2017) reported no differences in match-loss injury (n=129-202) count in the A-League between 2008-2013. However, limitations of the aforementioned study include delimiting the reporting to the hamstring, groin, knee and ankle injuries only, and injury count cannot be compared to the injury incidence in the other longitudinal league-wide injury epidemiology studies. Although overall league-wide injury rates seem to be stable, a longitudinal injury epidemiology comparing the injury rates inclusive of all injuries with more current A-League data is warranted.

2.5.2 Taxonomy of injury characteristics

To calculate an injury incidence, injury events need to be recorded. Such a process is dependent on the taxonomy of sports injuries for accurate between and within league comparisons (Orchard & Seward 2002). That is, a uniform injury classification system with a diagnostic criterion must be adopted given there is no standard of injury assessment (Orchard et al. 2010). The UEFA model suggests that injuries should be classed by location, type, body side, mechanisms and if it was a recurrent injury using the Orchard Sports Injury Classification System (OSICS) (Hagglund et al. 2005; Orchard et al. 2010).

Several disease and injury coding systems have been introduced such as the OSICS system and the Sports Medicine Diagnostic Coding System (SMDCS). The UEFA model proposes to use categorical headings based on the OSICS system, however, recommends combining categories for analysis of smaller sample studies. The SMDCS is a popularly used coding system developed in 1991 (Meeuwisse & Wiley). The classification system uses a three level six characer code denoted by two characters at each level . However, research regarding the validity and reliability of SMDCS has not been reported. In contrast, OSCIS version 8 and 9 are a 3 tier-figure coding system with parent groups related to location, pathology and further details (Hammond, Lilley & Ribbans 2009; Orchard et al. 2010). The OSCIS has had many revisions to improve inter-user reliability (Finch et al. 2014; Orchard et al. 2020; Rae & Orchard 2007). Finch et al. (2014) compared 1082 injury records coded by a physician and epidemiologists, with the first and second letters reporting 95.4% and 90.1% of agreed cases, respectively. However, caution should be demonstrated when using the third, which reduced to only 57.1% reproducibility. The fourth character is only used for unspecified or if insufficient detail is given in the first three characters. Hence, agreement was higher at 94.4% although the agreement level between physicians and epidemiologist for each character emphasises the importance of the background expertise the coder possesses (Finch et al. 2014; Rae et al. 2005). Given the inter-rater reliability reported for the OSICS system and consensus has recommendented its use, the literature suggest to use OSICS system in all soccer injury epidemiology studies moving forward. However, no other previous studies have reported on the measure taken to ensure reliability of the data.

Further classification of injuries by the region and type of injury varies between leagues and shows thigh injuries (particularly the hamstring) were the most common region of injury in Swedish (23%) and Danish (22%) premier leagues (Hagglund, Walden & Ekstrand 2005). Thigh injuries were also most common in the Spanish premier league in 2008/09 (36.6%) (Noya Salces, Gómez-Carmona, et al. 2014). Although European leagues generally reported muscle (~35%), joint/ligament (20%) and contusions (17%) as the most common type of injuries, injury types varied in Hong Kong and Nigerian premier leagues. Lee et al. (2014) reported contusions (30%), muscle (29%) then ligamentous (28%) injuries as the most common types in the 2010/11 season. However, throughout the Nigerian premier league, teams reported ligament (32%), muscle (17%) then tendon (7%) as the most common injuries in season 2011/12 (Ani 2015). The differences in injury incidence, injury type and regions demonstrate the inappropriateness of comparing injury epidemiology to other leagues and justify local league-based data collection and analysis to interpret injury contexts and trends.

Characterising injuries can guide practitioners in identifying risk factors and guide the injury prevention focus. The common injuries vary from league to league; however, with agreement of all league-wide studies adopting the Fuller et al. (2006) consensus statement injury region categories, injuries predominantly occur in the lower body (Table 2.4). Specifically, the thigh is the most common injury region in all leagues except for the Hong Kong and Kosovo

Leagues (Lee et al. 2014; Shalaj et al. 2016). In the thigh, the hamstring (67%) is the most common muscle to be injured, compared to the quadricep (33%) especially during competition (71%) (Hawkins et al. 2001). Of concern, the UEFA Injury Studies have reported that hamstring are rising at a rate of 2.3% per year in European soccer (Ekstrand, Waldén & Hägglund 2016). That is despite literature reporting hamstring injury prevention such as Nordic hamstring exercises is effective (Al Attar et al. 2017). However, Bahr, Thorborg & Ekstrand (2015) conducted a survey study in 50 UEFA teams and found that 83.3% of professional soccer players do not adapt and implement the Nordic hamstring exercise; representing one example where injury prevention maybe commonly known, but not implemented . Recent research shows increasing trend of hamstring injuries (Ekstrand, Waldén & Hägglund 2016), and players and club team officials are proactive in reducing injury. Therefore, further analysis on the hamstring injury trend is necessary to mitigate the risk of hamstring injury.

Table 2.4. Count and proportion (%) of injuries across injury regions in domestic professional soccer leagues.

	Calligeris, Burgess & Lambert (2015) - South African Super League		Fünten et al. (2014) - I & 2 Bundesliga		Lee et al. (2014) - Hong Kong Premier League		Noya Salces, Gómez-Carmona, et al. (2014) - Spanish La Liga		Shalaj et al. (2016) - Kosovo Super league	
	n	%	n	%	n	%	n	%	n	%
Head/face	10	8	11	4	5	2	35	3	5	2
Neck/cervical spine	2	2	2	1	2	1	-	-	3	1
Shoulder/clavicula	2	2	4	1	14	5	16	1	11	4
Upper arm	2	2	0	0	1	0	14	1	6	2
Elbow	0	0	1	0	3	1	0	0	11	4
Forearm	0	0	0	0	-	-	0	0	11	4
Wrist	1	1	1	0	5	2	0	0	7	3
Hand/finger/thumb	1	1	5	2	8	3	0	0	5	2
Sternum/ribs/upper back	3	2	7	2	4	1	19	2	7	3
Abdomen	0	0	3	1	2	1	11	1	4	2
Lower back/pelvis/sacrum	8	6	18	6	6	2	39	3	8	3
Hip/groin	16	12	12	4	35	12	175	14	22	8
Thigh	27	21	88	29	44	15	473	37	44	16
Knee	11	8	62	21	35	12	147	11	60	22
Lower leg/Achilles tendon	15	12	24	8	43	15	126	10	24	9
Ankle	27	21	50	17	48	16	185	14	26	10
Foot/toe	5	4	12	4	41	14	53	4	18	7
Total	130	100	300	100	296	100	1293	100	272	100

Another way of characteristing injury is by the type of injury (Table 2.5). In professional soccer, the most common injury is of muscle type followed by a ligament sprain (Ekstrand, Hagglund & Walden 2011; Fünten et al. 2014; Lee et al. 2014; Shalaj et al. 2016). Muscle injuries most likely relate to the high prevalance of hamstring injuries in professional soccer (Corazza et al. 2013; Hawkins et al. 2001). For example, an 11 year injury trend analysis showed that muscle injuries are increasing, whilst ligamentous injuries are decreasing in European leagues (Ekstrand et al. 2013). The ligament injury decrease may be related to the 7% per year decrease in medial collateral ligament (Lundblad et al. 2013) and 3.1% decrease of ankle injuries per season. However, these aforementioned findings only apply to European teams, as more detailed analyses of injury rates and types does not exist outside of Europe. In contrast, for Australian soccer player between 2008-/09-2012/13, hamstring and ankle injuries have remained stable between 12-22 injuries and 18-24 injuries, respectively. However, knee injuries halved from 78 in 2010/11 to 37 in 2012/13 (Gouttebarge & Kerkhoffs 2017). It would be plausible to suggest that some kind of knee injury prevention program was applied after 2010/11. However, given the lack of information available from the A-League, continued anlsysis of Australian injury data is necessary to guide injury prevention of key injuries.

Table 2.5. Count and proportion (%) of injury type in professional soccer leagues.

	aus der Fünten et al. (2014) – Bundesglia I and 2		Lee et al. (2014) – Hong Kong League		Shalaj et al. (2016) – Kosovo League	
	n	%	n	%	n	%
Fracture	15	5	7	2	7	3
Other Bone Injury	5	2	-	-	1	<0
Dislocation/subluxation	2	1	2	1	17	6
Sprain/ligament injury	74	25	84	28	57	21
Meniscus/cartilage	9	3	3	1	22	8
Muscle injury/strain	98	33	85	29	65	24
Tendon injury	15	5	5	2	13	5
Haematoma/contusion	54	18	90	30	58	21
Abrasion	4	1	5	2	20	7
Laceration	3	1	0	0	7	3
Concussion	4	1	2	1	4	1
Nerve Injury	0	0	-	-	0	0
Synovitis/effusion	-	-	-	-	-	-
Overuse Complaint	-	-	-	-	-	-
Other Type	17	6	13	4	1	<0

The mechanism resulting in injury can dictate how injury prevention should be approached i.e. modification training, physical loading or even changing of the sports laws (Bahr & Holme 2003; Windt & Gabbett 2017). In one La Liga team, a 5 year surveillance showed 70% of injuries were due to non-contact mechanism (Larruskain et al. 2018). Similarly in the Brazilian premier league, non-contact injuries amounted to 80% of all injuries (Reis et al. 2015). Across multiple teams, the dominance of non-contact mechanism injuries was confirmed in 7 Hong Kong Premier League teams; however, the non-contact injuries were less pronounced at 55% of all injuries (Lee et al. 2014). Accordingly, it is evident that non-contact injuries remain a key mechanism of focus for injury surveillance and prevention.

From analysis of soccer injury mechanisms, Hassabi et al. (2010) reported that 16% of injuries were sustained whilst running as the most common mechanism of injury in one Iranian Premier League club. Similarly, in 4 season of 4 English Premier League clubs, 69 out of 391 match-based injuries and 30 out of 187 training-based injuries were sustained as a result of running related actions (Hawkins et al. 2001). Conversley, in the Saudi Arabian Premier league, all 14 team reported that contact injuries, particularly with another player, was the most common reason for injury (Muaidi 2019). Muaidi (2019) suggested that the greater contact injuries may be league-specific attitudes toward fairplay. However, it should be noted that the previously mentioned Saudi Arabain study was only reported for one season and it is unknown if the greater contact injuries was just a non-significant fluctuation. Therefore, reporting an updated trend of injury mechanism in soccer is necessary for sports ogranisers and coaches to effectively implement strategies to ensure player health and safety given the demands of the game.

Time-loss injuries are typically categorised into four distinct lay off periods - <3 days = slight severity, 4-7 days = mild severity, 8-28 = moderate severity and > 28 days = major severity (Fuller et al. 2006). The severity of such injuries may result in health, financial and performance costs (Eirale, Tol, et al. 2013; Ekstrand 2013; Gouttebarge & Kerkhoffs 2017). As shown in Table 2.7, most injuries sustained in professional soccer result in less than 3 days time-loss (Hägglund, Waldén & Ekstrand 2003; Noya Salces, Gomez-Carmona, et al. 2014; Waldén, Hägglund & Ekstrand 2005). As further evidence, Ekstrand et al. (2020) studied 22942 injuries from UEFA league and concluded that most injuries are mild (<7 days). Awareness of the time-loss due to injury is important for clubs in forcasting the cost of an injured player (Bahr, Clarsen & Ekstrand 2018; Gouttebarge & Kerkhoffs 2017; Hickey et al. 2014). In turn, understanding injury time-loss from a national federation perspective is important so serious financial risk can be intercepted with measures to reduce or prevent the impact of injury. Understanding this cost is also important to provide realistic expectations to practitioners on the return to play timeline and best practice approach to rehabilitation (Ekstrand et al. 2020). Thus, ongoing analysis on the severity of injury is necessary so clubs can forcast financial expendiature and losses and strategies can be implemented to ensure sustainability of both clubs and the league.

Table 2.6. Injury incidence in each severity group in professional soccer players.

Author/s	League	Surveillance Period	Team (n)	Slight Severity (1-3 days) (/1000h)	Mild Severity (4-7 days) (/1000h)	Moderate Severity (8-28 days) (/1000h)	Major Severity (>28 days) (/1000h)
Hägglund, Waldén & Ekstrand (2003)	Swedish Premier league	1982 and 2001	1982= 12 ; 2001=14	1982=2.8; 2001=36.9	1982=1.7; 2001=30.84	1982=1.5; 2001=34.3	1982=0.6; 2001=9.7
Waldén, Hägglund & Ekstrand (2005)	UEFA Clubs	2001-2002	11	2.6	2.7	2.8	1.4
Hagglund, Walden & Ekstrand (2006)	UEFA Clubs	2001 -2002	12	2001=2.3; 2002=2.8	2001=2.1; 2002=2.1	2001=2.5; 2002=1.9	2001=0.8; 2002=0.8
Ekstrand, Hagglund & Walden (2011)	UEFA Clubs	2001-2008	23 UEFA	1.7	2.1	2.9	1.2
Bayne et al. (2018)	South African Premier Soccer League	2015/16	2	0.0	0.0	0.1	0.0
Hägglund, Waldén & Ekstrand (2005)	Swedish Premier league & Danish Super League	2001	8 Danish; 12 Swedish	Danish=6.2; Swedish=2.9	Danish=3.51; Swedish=1.9	Danish=3.04; Swedish=2.5	Danish=1.68; Swedish=0.7
Jones et al. (2019)	English Premier League & National Conference	2015/16	10	0.4	3.5	4.0	1.3
Noya Salces, Gómez-Carmona, et al. (2014)	Spanish La Liga	2008/09	16	2.0	1.5	1.6	0.5
Noya Salces, Gomez-Carmona, et al. (2014)	Spanish Division 2	2008/09	11	2.2	1.3	1.5	0.5
Shalaj et al. (2016)	Kosovo Premier League	2013/14	12	1.2	2.5	2.9	0.7
Stubbe et al. (2015)	Dutch Premier Soccer League	2009/10	8	1.1	2.0	2.1	1.0

2.5.3 Understanding Soccer Injury Epidemiology

As part of using injury epidemiology data, practitioners should be aware of the biases in different statistical procedures and data handling (Robinson 2009; Schwartz 1994). Epidemiology studies adopt an ecological study design which aggregates an individual data into a group as a unit of analysis to develop or test a hypothesis (Morgenstern 1982; Piantadosi, Byar & Green 1988). In the present literature review, a single injury event can be denoted as an individual. Ecological data may offer valuable clues about the behaviour of individual samples; however, fallacies can occur if assumptions are made from one level of analysis to another (Robinson 2009). That is, injury trends that either increase, decrease, or stay stable at league level can be completely different or the opposite when team or individuals are used as the unit of analysis (Schwartz 1994). The mistaken interpretation can be the root of perceived ineffective injury prevention.

Wakefield (2009) suggests a hybrid study design of analysing both ecological and individual data to overcome possible ecological fallacy. Only two soccer injury epidemiology studies have previously attempted to investigate the effect of their data structure. In a 6 year prospective study of Norwegian professional soccer players, Bjørneboe, Bahr & Andersen (2014) accounted for inter-team variation and clustering effects whilst using a general estimating equation model. Comparing the injury rate between the use of a Poisson linear regression model and a general estimating equation model, the linear regression model estimated that injuries would increase 1.06 acute match injuries/1000h (95%CI:0.40-1.73). Conversely, the inter-team variation and clustering effects has a significant affect with injury incidence increase by 0.92*95%CI: -0.11-1.95, p=0.083). In another example, Ekstrand et al. (2013) analysed time-trends of injuries sustained between 2001 to 2012 and used a linear mixed model accounting for differences between the ‘core 4 teams’ (Arsenal FC, FC Internazionale Milano, PSV Eindhoven, and Real Madrid CF) identified by their historical success. Ekstrand et al. (2013) reported that ligament incidence rate decreased at a rate of 4% per year whilst the ‘core 4 teams’ accounted for 60% of the explained variance in the model. This means that the decrease in ligament injuries was not equal in all teams. The two mentioned examples highlight the need to consider team variation that underlies injury incidence rates and trends. This is particularly important as decision making can be erroneous if the findings are applied to the incorrect level of analysis. This is of particular importance for national federations who are responsible for medical policies governing club operations for injury surveillance and prevention programs. Hence, future injury epidemiology analysis in Australian and other leagues should consider team variation in a linear mixed model when reporting league-wide injury data.

2.6 The Cost of Professional Soccer Injuries

Separate from health perspectives, the consequences of injury can categorized by financial or performance cost, and is suggested both should be considered in any analyses (Ekstrand 2016). The incidence of injury, particularly severe injury or injuries with long term effects can discourage participation and result in lost revenue for clubs (Garcia-del-Barrio & Szymanski 2009). This next section will focus on the myriad of negative consequence on associations, teams and individual players.

2.6.1 Salary cost of injury in soccer

The player-salary cost of injury is driven by the amount of days missed and can be used as a marker of injury prevention success (Association 2016; van Mechelen, Hlobil & Kemper 1992). In the A-League, the annual Professional Players Association injury report highlighted 156 injuries resulted in 669 missed matches that accumulated to an injury cost of \$4.3 million in the 2015/16 season (PFA 2016). Gouttebarge & Kerkhoffs (2017) reported the financial cost of injury was at ~\$4million in season 2008/09 before peaking at ~\$6 million in the season (2010/11) prior to MMS which reduced to ~\$3.3 million in season 2012/13. The salary cost analyses indicate that MMS has had a positive impact compared to seasons prior to the MMS; though since then, the cost of injuries has since plateaued (Gouttebarge & Kerkhoffs 2017) The cost of injuries in the A-League is noticeably less than in the UEFA Champions League, as the cost reflects the salary capped value of players. Injuries sustained from a UEFA Champions League squad of 25-28 players results in an average of 1100 days per season and €20 million per season (Ekstrand 2016). However, obviously in the UEFA Champions

League signing players is comparatively expensive to players in the A-League which comes with the salary capped A-League. Though it is worth highlighting the limitations from both studies. That is, the ongoing medical costs or recurrent injury costs, hospital cover and loss of income is not reflected in this estimated financial cost. Examining current league-injury cost can ensure all players are protected with minimum medical care regardless if clubs experience financial hardship or financial favour regular starting players (Drawer & Fuller 2002a). Currently the financial cost of injury in the A-League is unknown as the most recent data is out of date. Therefore, the financial cost of injury data from the A-League should be profiled over several seasons to assess if the financial cost has meaningfully changed to prompt if revision of medical regulations is required.

2.6.2 Effects of professional soccer injuries on team performance

Injuries have been reported to impact athlete performance which bore into poor team performance (Arnason et al. 2004b; Eirale, Tol, et al. 2013; Hägglund et al. 2013). A prospective UCL cohort study reported that teams with four players unavailable is associated with more sprints, greater total distance and distance ran at or above high speed (>14km/h) (Windt, Ekstrand, et al. 2017). In a five-season study of teams in French Ligue 1, winning teams had lower squad utilisation, total running distance and high-speed (Carling, Le Gall, et al. 2015). It was reported that greater player availability allowed first choice players to continue to be used and as a result teams did not require to run as much or fast, given first choice teams are more experienced and tactically skilled (Carling, Le Gall, et al. 2015). That said, research has suggested that squad rotation and post-match recovery may be efficient in dealing with player unavailability and distributing workloads, that if accumulate in one player, may significantly increase injury risk (Carling, Le Gall & Dupont 2012).

The aim of any professional sport is to win matches and championships; however, studies suggest that injuries may affect the probability of winning (Finch 2017). In a correlation analysis Eirale, Tol, et al. (2013) reported that a lower injury incidence was strongly associated with team ranking position ($r=0.929$, $p=0.003$), total points ($r=0.929$, $p=0.003$), goals scored ($r=0.893$, $p=0.007$) and games won ($r=0.883$, $p=0.008$). Similarly, in an 11-year study of 24 UEFA teams, less days lost to injury and match availability of players were significantly associated with better league ranking ($\beta=-0.009$ (95%CI:-0.017 to -0.002; $p=0.015$ and $\beta=0.086$ (95%CI:0.005 to 0.168; p=0.0.037, respectively) and more points per match ($\beta=-0.002$ (95%CI:-0.003 to -0.001; $p<0.001$ and $\beta=0.019$ (95%CI:0.009 to 0.029; p=0.0.037, respectively); however, the magnitude of the association is small (Hägglund et al. 2013). The contrast in the strength of the associations may hint that performance may be more complex. For example, the aforementioned studies do not consider how the individual players contribute to team performance or the opposition for any given match data. Given these limitations of interpreting injury and performance, further analysis including other predictor variables is necessary.

Although national bodies do not directly impact the training or rehabilitation of athletes, the injuries sustained by athletes hinder the sustainability of clubs through poor performance related to player unavailability (Parry & Drust 2006). Injuries often lead to a lay-off time for rehabilitation which may reduce or disrupt regular match exposure (Ekstrand 2013). With the loss of match time, players reduce their chances of earning their maximum salary (Késenne 2000). To systematically allocate medical resources, the process should be guided by the financial cost of injury, the effect of injury on the athlete in the short and long term, and performance cost on the team. Accordingly, a lack of evidence exists on either the financial or team performance cost of injuries in the A-League and further longitudinal research is required to understand these relationships.

2.7 Provision and Infrastructure for Athlete Care in Professional Soccer

The provision and infrastructure of athlete care surrounding an athlete is an integral part of their health, wellbeing and success. In professional soccer, team officials (i.e. the coaches, managers, medical staff, etc.) are tasked to balance injury risk while optimising performance. Currently, limited evidence exists regarding the extent and change in medical service provision in professional football (Drawer & Fuller 2001; Malcolm, Scott-Bell & Waddington 2017; McCall et al. 2015). This next section will explore the limited literature on the provision and infrastructure of athlete care in professional soccer clubs.

Over the past 3 decades, the provision and infrastructure of athlete care has changed with the growth of sports medicine. In a scientific magazine article, Lewin & Lewin (2018) outlined the growth of the medical-related departments at Arsenal Football Club. Of note, over 30 years Arsenal have appointed many sports medicine related roles including a sports doctor and high-performance manager. Whilst there seems to be growth in the number of team officials and the resources available in a wealthy club such as Arsenal and other European clubs, there is no literature exists on medical staffing or provision in leagues outside of England (Lewin & Lewin 2018; Malcolm, Scott-Bell & Waddington 2017). Given the stagnant injury trends, it is imperative for sporting organisations to know what provisions and infrastructure of athlete care exist within clubs so that support for clubs can be provided effectively.

An integral part of athlete care are the doctors and physiotherapists (Malcolm, Scott-Bell & Waddington 2017). Given these practitioners are the respective first contact and key providers of athlete medical care, as well as setting injury prevention direction, and understanding of their existence and role is critical for injury infrastructure and provision. In a qualitative study of professional English soccer 1997 to 1999, only 6 of 58 club doctors and 27 of 53 club physiotherapists were charted professionals (Waddington, Roderick & Naik 2001). The result from the survey reported poor appointment practices and underqualified, inexperienced upon appointment and underpaid club 'medical professionals' raising concern of the quality of care provided to players (Waddington, Roderick & Naik 2001). Poor appointment methods may bring a conflict of interest for medical decisions and compromise athlete care and safety (Waddington, Roderick & Naik 2001). That is, there may be ethical challenges for practitioners to declare a player fit for playing, provide aggressive treatment, or even deem a player unfit for matches (Dijkstra et al. 2014; Greenfield & West 2012; Law & Bloyce 2019). Despite a follow up study reporting medical and healthcare provision improvements in appointing health care professional, the potential of improvement is still more conceptual than evidence-based (Lewin & Lewin 2018). In a survey study of 44 professional soccer clubs from various premier leagues, McCall et al. (2014) reported a mean and standard deviation of 2.5±1.4 physiotherapist, 0.8±1.1 doctors and 1.6±1.0 sport scientist which combined to an average of 5.1±2.4 practitioners involved in injury prevention programs within their premier league clubs. Comparably, Malcolm, Scott-Bell & Waddington (2017) used the same survey methods mentioned earlier to report an increased to 2.9 doctors and 5.2 physiotherapists per premier league club (Malcolm, Scott-Bell & Waddington 2017). However, a limitation of the findings is the poor response rate from both doctors (35.8%) and physiotherapists (45.6%). Nonetheless, there is a clear increase in the number of employed chartered professionals in medical departments, though it should be mentioned that the volume of appointed professionals does not necessarily provide better quality care. Whilst further improvements in appointment processes are needed, the aforementioned studies hint clubs are looking at ways to improve the provision and infrastructure of athlete care (Malcolm, Scott-Bell & Waddington 2017). Such ongoing analyses are completely absent in most leagues, including the A-League. Hence, an outline of the sports medicine provision and infrastructure available in Australia soccer clubs may provide further insight on the inadequacies so that they can be addressed to ensure better athlete care.

An example of the concern of consequences of limited medical support is shown in previous research has reported that inadequate athlete care in clubs may lead to long term consequences (Drawer & Fuller 2002b). In a survey of 500 retired English Professional Footballer's Association players, services of injury prevention resources and support, such as sport science or education/welfare provided by clubs, were perceived as inadequate prior to acute and chronic injuries (Drawer & Fuller 2002). It is possible that the perceptions reported in the previously mentioned study may be outdated or that practices have changed from 18 years ago. In an editorial, Buchheit et al. (2019) discussed the challenges of navigating through a plethora of new injury prevention research and suggest that injury prevention is implemented but may not necessarily be effective. Additionally, the complexity of injury prevention needs to realised in the context of professional soccer environments (Buccheit 2017). For example, in 33 UEFA elite clubs, 94% of teams completed musculoskeletal screening whilst 87% performed it continuously in the pre- and in-season (McCall, Dupont & Ekstrand 2016). However, whilst these findings show engagement in preventive practices, the usefulness of musculoskeletal screening continues to be debated; as debate suggests such practices are not predictive of injury, whilst others report usefulness to identify physical capacity weaknesses/imbalances (Bahr 2016; Buckthorpe et al. 2019).

Collectively, there is limited information on the provision and infrastructure of athlete care in any league. The responsibility of national federations or sport governing organisations is to implement policy and set precedent to all players and clubs. Hence, the MMS may be an example of an injury reducing policy available to a national federation. However, there are no studies which outline the changes in the provision and infrastructure in athlete care in the A-League or other professional soccer leagues.

2.8 Theoretical Frameworks of Injury Prevention: an organisational perspective.

Reducing the incidence of injuries and the ensuing cost of injury is the primary focus on sports medicine practitioners. Despite such Hippocratic perspectives, injuries are complex, multi-faceted issues where difficulties exist in the prognosis, determination of cause and provision of evidence-based treatment (Bahr & Holme 2003; Drew, Cook & Finch 2016; McCall et al. 2014). A conceptual framework offers researchers and practitioners a systematic approach underpinning the development of comprehensive understanding and robust protocols (Finch 2006; O'Brien et al. 2019; van Mechelen, Hlobil & Kemper 1992). To reduce injury incidence, different sports have generally adopted the use of 'sequence of prevention' of injuries model and adapt the framework into their environment (van Mechelen, Hlobil & Kemper 1992). Recognising that injury prevention models are not the focus of this thesis, national federations who oversee leagues still have a role to understand injury causation and factors affecting injury in football. Accordingly, the next section will introduce the idea of injury prevention from an organisational perspective as opposed to the traditional direct athlete approach.

2.8.1 Injury prevention frameworks

The 'sequence of prevention' model was first introduced by van Mechelen et al. (1992).This four-step model (Figure 2.2) is derived from a public health prevention model and implies that injury prevention starts with quantifying the extent of the injury problem (van Mechelen, Hlobil & Kemper 1992). However, simply identifying the problem cannot prevent injuries and thus, the mechanisms and risk factors of injury must then be identified (Bahr & Holme

2003). Following this identification, targeted injury prevention protocols can be developed and implemented (van Mechelen, Hlobil & Kemper 1992). Lastly, the success of injury prevention protocols must be evaluated through post-intervention injury incidence and severity. Although such steps seem intuitive, previous literature have also identified several issues related to ongoing injury prevention outside of the intervention period are not considered (Chalmers 2002). As a result, Finch (2006) proposed the 'Translational Research into Injury Prevention Practice' framework dicussing that the lack of examined injury prevention success is due to the omission of real-life considerations (Figure 2.3). That is, interventions studies are conducted in an artifical enironment where resource support is a given. Many prevention programs require resources such as skilled and/or enough personnel to perform treatment or deliver preventative programs, equipment and space (Finch 2006). The previously mentioned frameworks can be viewed from a national sports organisation perspective (Bolling et al. 2018). For example, the prevention steps may include a league wide injury surveillance program to understand the injury situation and evaluate injury prevention. Further, injury prevention may be implemented in the form of policies, such as an MMS as an injury prevention intervention, as opposed to a randomised control trial of a physical injury prevention program. Regardless, such injury frameworks should still be considered by governing bodies when implementing injury surveillance and prevention practices (Bolling et al. 2018).

The most recent version of injury prevention frameworks is targeted for team-sport environment. O'Brien et al. (2019) introduced the Team Sport Injury Prevention Model (Figure 2.4). The framework builds from the van Mechelen (1992) sequence of injury prevention; however, this present model places emphasis on the contextual understanding of the environment the injury prevention will be implemented into. In the present, no soccer injury epidemiology studies outline the context in which the reported injury exists. Hence, future research should explore the (R)evaluation phase. From a national perspective, if injury prevention is implemented via policy, clubs will forced to address issues of skilled personnel, compliance and resourcing. Whilst not all previously mentioned aspects are practical; understanding the current provision and infrastructure of athlete care can guide policy that is theoretically achievable by all teams within a given league.

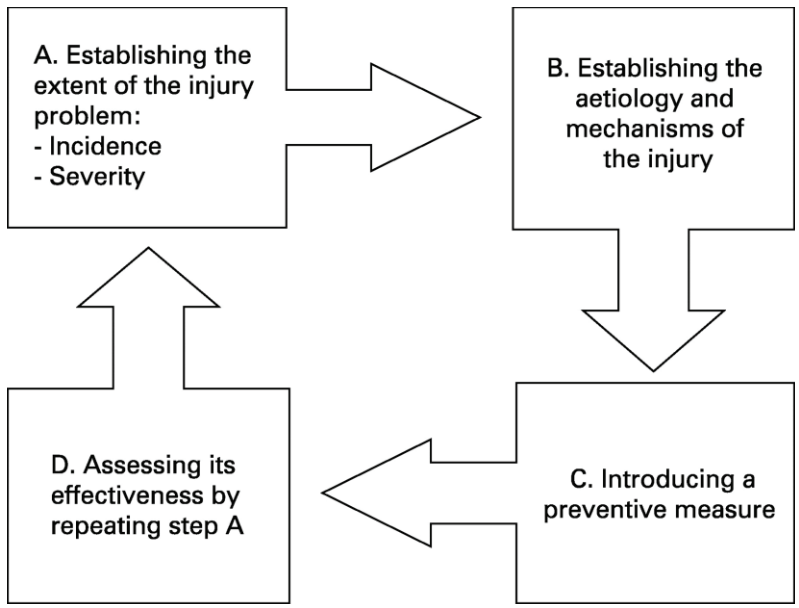

Figure 2.2. Sequence of Prevention (van Mechelen, Hlobil & Kemper 1992).

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	

Figure 2.3. Translational Research into Injury Prevention Practice framework (Finch 2006).

Figure 2.4. The Team-sport Injury Prevention (TIP) cycle (O'Brien et al. 2019).

2.8.2 Injury prevention from an organisational perspective

The negative consequences of injury exist for health, finance and performance for the player, club and in turn the sporting organisation (Eirale, Tol, et al. 2013; Ekstrand 2013). However, injury prevention is commonly viewed as the responsibility of the medical practitioners to provide primary care. Whilst injury prevention is often developed at the level of the athlete to provide direct effect, the implementation of prophylactic policy exists to guide infrastructure, resources and provision of athlete care by sporting organisations as part of primary prevention needs. This section of the literature review uses the models outlined previously, to explore their fit to an organisational injury prevention context. At the organisational level (league or national federation) a prevention program requires exposure to the preventative effect to all those under the intervention. Prevention at the organisational level may be in the form of a league-wide implemented physcial program or policy. An advantage of a sporting organsiation is the ability to govern and overcome the mentioned issues with research to practical translation.

The Fédération Internationale de Football Association (FIFA) Governance Regulations (2016) outlines that all FIFA bodies have the responsibility of developing medical guidelines for all coaches, players, referees and assistant referees. The regulation leaves a gap for individual bodies to enforce competition specific medical regulations. The aim of any MMS is to support policy regarding strategies aimed at reducing injuries / mitigating injury risk (Gouttebarge & Kerkhoffs 2017; Vouillamoz 2016) The MMS can be thought of as a league-based injury prevention approach by combining team- and individual-based injury prevention approaches and addressing the issues that may prevent injury prevention success. In the first step of the ‘Team-Sport Injury Prevention” framework, the injury situation needs to be investigated (O’Brien et al. 2019). Currently, there are a few leagues that implement standardised injury surveillance; however, more longitudinal league-wide injury epidemiology studies have yet to be reported (Bjørneboe, Bahr & Andersen 2014; Gouttebarge & Kerkhoffs 2017). Hence further injury longitudinal injury epidemiology from a whole league needs to be reported used to evaluate league-level injury prevention.

In understanding the injury situation, the current injury prevention situation also needs to be reported (O’Brien et al. 2019). Currently, there is limited information on the provision and infrastructure of athlete care and how it relates to injury. Of the information available, the provision of athlete care in professional soccer was previously poor (Drawer & Fuller 2002b). However, recent research suggests that the provision of care has changed, given 47.7% and 43% of 44 premier league soccer clubs implemented injury prevention 2 to 5 times per week in preseason and in-season, respectively (McCall et al. 2014). McCall et al. (2014) also reported from premier league clubs that testing for injury risk factors did occurred via functional movement screening, questionnaires and isokinetic testing. Future research should investigate the provision and infrastructure of athlete care and the changes, or lack of, with concurrent injury trends in the A-League. Such an investigation may identify the standard of care related to the reduced A-League injuries, particularly given the changes to the MMS.

Gouttebarge et al. (2017) speculated that there was an effect of the of the A-League MMS given the concurrent implementation and a reduction in the injury-induced missed matches and related costs in the following season (2011/12). There are several advantages of implementing policy as an injury prevention intervention, particularly surrounding compliance and funding. Under the MMS, all A-League clubs are obligated to conduct prevention programs with sound evidence, provide mandatory resources, and defined rights of a player to their own medical care and management (Professional Footballers Australia 2015). Further, prophylactic strategies can be limited by financial input by clubs and consequent social problems for players may arise. For example, UEFA provided a revenue funded Minimum Medical Requirements and may be feasible for other leagues too. However, preliminary studies are warranted to identify the kind of medical infrastructure and provisions available in Australian clubs to then understand the effectiveness of the A-League MMS in reducing injuries.

2.9 State of the Literature

The increased popularity and interest in Australian soccer continues to result in greater stakeholder demand for better athlete care, particularly given injuries have a possible negative consequence of playing soccer. Soccer injuries are widely investigated in professional leagues around the world; however, in the A-League only one study has reported injury epidemiology between 2008/2009 to 2012/2013 seasons. Hence, an update on Australian soccer league-injury epidemiology is warranted.

Understanding the factors that affect injury incidence can assist with more accurate inferences and subsequent injury prevention success. Methodological issues such as inconsistent definitions, calculations, and reporting styles have made it difficult to compare between studies (Fuller et al. 2006). As a response, a consensus statement on the methods of soccer-injury epidemiology published and the consensual methods were piloted on two European leagues (Hagglund, Walden & Ekstrand 2005). However, competition variability due to number of teams registered, an open system (i.e. promotion and relegation), and simultaneous continental competitions make it difficult to translate the results to Australian contexts. Therefore, a study controlling potential confounding factors of injury is valuable in understanding the meaningful factors underlying injury incidence patterns. Thus, research in an Australian setting is both important to the local organisation and can have implications on a broader scale due to the closed-league nature of the competition.

Greater injury prevention success is purported to reduce the financial, health and performance cost of injuries on teams and individual players. To ensure that the MMS, is effective, another marker of assessing the success of injury prevention is the financial cost of injury.

Additionally, performance should also be considered given the influence of financial revenue to fuel the sustainability club and avoid bias medical provision towards first team players (Késenne 2000). Significant negative changes in cost whether on finance or performance should prompt changes in medical regulations. Hence, a financial and performance cost analysis due to injury in the A-League is necessary.

Although single-team intervention studies exist, collectively the studies report conflicting results in reducing injuries from targeted interventions (Al Attar et al. 2017; Croisier et al. 2008; Soligard et al. 2010). In Australian professional soccer, teams are contracted to provide athletes with a ‘minimum medical standard’ of care. That is, all teams competing in the A-League must comply with the MMS, which are implemented to reduce injury incidence. In the present, is it known that implementation of MMS, is followed by reduced injury incidence (Gouttebarge & Kerkhoffs 2017). However, it is unknown why or how the MMS, results in MMS. Hence, the changes to medical provision of Australian soccer players should be reported with concurrent injury epidemiology.

Chapter 3 : Study 1

Injury epidemiology in Australian male professional soccer

As based on a paper:

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3.1 Abstract

Objectives: To describe the injury epidemiology of the Australian male professional soccer league (A-League) over 6 consecutive seasons. *Design:* Prospective observational cohort study. *Methods:* Match-loss injury data was collected from each A-League club (n = 10) for each competition match (n = 27/season) over 6 seasons (2012/13–2017/18). Injuries were collected weekly through a standardised protocol and were classified by setting, mechanism, severity, type, and location on the body. Poisson Regression Models were used to estimate the injury incidences (injury/round/season), whilst rate ratios were reported for total injuries and within abovementioned injury classifications. *Results*: Overall injury incidence was not significantly different ranging from 4.8 (95%CI:4.1–5.8) to6.7 (95%CI:5.8–7.8) between seasons 2012/13 to 2017/18 ($p > 0.05$). Match injuries remained stable whilst training injuries decreased across the 6 seasons (exp(β) 0.59[95%CI:0.36–1.0]; $p = 0.04$).Respectively, contact and non-contact injuries were not significantly different across the 6 seasons, although non-contact injuries were more common than contact injuries ($p > 0.05$). Mild severity injuries decreased (exp(β) 0.64 [95%CI:0.4–0.9]; $p = 0.02$), whilst moderate severity injuries increased (exp(β)1.7 [95%CI:1.0–2.8]; $p = 0.04$) in season 2017/18 compared to 2012/13. The most common injuries were at the thigh (23–36%), of which the majority were hamstring injuries (54%–65%) of muscle/tendon type (50–60%of total injuries/season). Injuries remained stable across the seasons by type and location ($p > 0.05$ and $p > 0.05$, respectively). Conclusions: Injury rates, mechanisms, locations, and types have remained relatively stable over recent seasons of the A-League. Current Australian professional soccer league medical practices may have contributed to the stability of injury rates.

3.2 Introduction

Injuries result in adverse medical, socioeconomic and performance effects on players, clubs and leagues in professional soccer, highlighting the importance of continued focus on injury prevention strategies (Drawer & Fuller 2002b). As part of this process, systematic studies of injury epidemiology are required to prioritise highly prevalent and severe injuries and understand patterns of incidence to drive appropriate intervention foci (van Mechelen, Hlobil & Kemper 1992). League-based injury epidemiology studies have reported overall injury incidences between 5-8/1000 playing hours, with training injuries (2-5/1000 playing hours) commonly lower than match-based injury incidence rates (30-60/1000 playing hours) (Eirale, Farooq, et al. 2013; Noya Salces, Gómez-Carmona, et al. 2014). Few soccer injury epidemiology studies have reported multi-season data from locations outside of Europe, making it difficult to deduce either seasonal injury trends, or trends from other continents. The lack of multi-season, geographical-specific, league-based injury data from the Asian region has prompted the Asian Football Confederation (AFC) Medical Committee to call for greater reporting of injury surveillance from member federations (Eirale et al. 2017).

Longitudinal injury epidemiology analysis can profile the patterns between risk factors and incidence. In the Japanese Premier League over 15 seasons (1993 to 2007 seasons), injury incidence had a non-significant decrease ($p=0.118$) (Aoki et al. 2012). Stable overall, match and training injury incidence were also reported in 23 Union of European Football Associations (UEFA) teams between seasons 2001/02 and 2007/08 (Ekstrand, Hagglund & Walden 2011). Further, in the aforementioned epidemiology report muscle/tendon injuries at the hamstrings were most common, showing an increase of 2.3% per year in a further analysis of 36 UEFA Clubs (Ekstrand, Waldén & Hägglund 2016). However, the contribution of these injuries to the overall injury incidence vary between leagues and are contrary to the generally stable overall injury incidence rates (Ekstrand, Waldén & Hägglund 2016; Werner et al. 2019). Hence league-specific injury epidemiology over multiple seasons is important to guide the investigation of injury mechanism and aetiology.

The Australian male professional soccer league (A-League) has been active for 13 consecutive seasons in its current guise; though injury incidence and characteristics have only been reported in the research literature once, for seasons 2008/09 to 2012/13 (Gouttebarge & Kerkhoffs 2017). From this work, time-loss injuries peaked at a total of 202 injuries in the 2010/11 season before decreasing to ~160 total injuries in the following two seasons. Time-loss injuries also showed a similar trend, peaking with 1100 missed matches in season 2010/11 and reducing to 760 missed matches in season 2011/12. Of note, despite this novel reporting, the study is limited by a lack of comparable injury rate or incidence rate ratio. Additionally, the injury count was limited to hamstring, groin, knee and ankle injuries not reflecting the full extent of injuries in this competition. Hence an updated A-League injury epidemiology, inclusive of all injury types from standardised collection methods is necessary. With such an update, national league stakeholders can evaluate previous practices to inform effectiveness of injury prevention in future seasons.

Given the lack of comparable Australian injury data and importance of injury epidemiology data to guide effective injury prevention, injury epidemiology reporting from recent seasons of the A-League is necessary. Therefore, this study aims to 1) report the injury incidence in the A-League between 2012/13 to 2017/18 seasons, and 2) describe the frequency of injury type, location, mechanism, and number of missed matches in these 6 seasons.

3.3 Methods

A prospective cohort study of 421 players in the A-League was undertaken between seasons 2012/13 to 2017/18. A standardised injury surveillance system collected injury data from all A-League teams (n=10) for 6 consecutive seasons. Each season consisted of 27 matches (October to April) from the A-League competition, equating to 810 matches played over the 6 seasons. A full-time physiotherapist of each team recorded injury data daily and reported weekly injury surveillance data using the Football Federation Australia Injury Surveillance spreadsheet, which was forwarded to the Injury Surveillance Officer. Given reporting of data is part of medical policy, compliance of submitting injury surveillance data was 100%. Each player signed a release of medical records form as part of their A-League contract under the Collective Bargaining Agreement. Permission for the use of the medical data was granted by Football Federation Australia. The study design was approved by the Human Research Ethics Committee (UTS REF: ETH18-2324; Appendix A).

A time-loss injury definition was adopted from Fuller et al. (2006) with specific references to A-League matches in that '*any physical complaint requiring medical attention resulting* *in a missed A-League match'*. Injury surveillance sheets collected when an injury occurred and if they occurred in an official A-league match, training or from an 'other' setting. An 'other' injury is defined as an injury occurring outside of an official A-League match or training; however, still resulting in a missed official A-League match. All match, training and 'other' injuries were included in the overall injury incidence. The Injury Surveillance spreadsheet also recorded number of missed matches, type, location and mechanism of injury. Injuries were divided into a severity category based on the number of consecutive missed matches – mild (1 missed match), moderate (2 – 4 missed matches) and severe (5 or more missed matches).

Injuries were dichotomised into contact or non-contact mechanisms, where contact injuries are those resulting from physical contact with another player or object. Non-contact injuries refer to an injury event resulting from an athlete imposing excessive force within their body (Alentorn-Geli et al. 2009). Classification for injury location and type groupings were based the FIFA Assessment and Research Centre Injury Consensus Group statement (Fuller et al. 2006). All injuries were recoded from the Sport Medicine Diagnostic Coding System to the Orchard Sports Injury Classification System by the injury surveillance officer with consultation of 2 sports physicians and a physiotherapist (Meeuwisse & Wiley 2007; Orchard 1993).

Injury were aggregated to counts, overall and by subgroups (setting, mechanism, type and location), across the league for each match (n=27 matches/season) and per season (n=6).

Injuries were expressed per rounds as exposure in terms of time played was not collected. Season 2012/13 was used as the reference season. Trends in total injuries by season were evaluated using Poisson regression models. An assessment of over-dispersion was made for each model by comparing the mean and variance and, if found, a quasi-Poisson model was used. Models with a continuous representation of season tested for a linear trend, while a categorical representation of season was used to evaluate possible non-linear trends in injury. Interaction models with pairwise comparisons were used to assess differences in injury setting, mechanism, type and location across the 6-season period. The incidence of concussion, quadriceps/lateral thigh, hamstrings and anterior cruciate ligament injuries were further analysed over the 6 seasons in separate models due to high prevalence and severity of injury consequence. Incidence estimates per match per season and 95% confidence intervals (CI) for the 6 seasons were reported. Rate ratio (RR) was reported by exponentiating the intercept and slopes. A rate change of less than 1 resulted in injury incidence reduction whilst a rate change above 1 related to an increase in injury incidence. All analysis was conducted in the R statistical language with the packages ‘MASS’ and ‘emmeans’ (Lenth, Singmann & Love 2018; Team 2013; Venables & Ripley 2002).

3.4 Results

A total of 917 injuries were recorded from 421 players competing in the A-League over the 6 seasons were included in the analysis. The total number of injuries in the 6 consecutive seasons were 164, 152, 182, 121,146 and 151, respectively, between 2012/13 to 2017/18. The estimated total injury incidence/round ranged between 4.8 (95%CI:4.1-5.8) to 6.7

(95%CI:5.8-7.8), without any significant differences between seasons (Figure 3.1A; $p>0.05$). Further, the occurrence of an injury was unaffected by the week within a season ($\exp(\beta)$ 0.99 (95%CI:0.98-1.00); $p=0.119$).

Over 6 seasons of analysis, injuries were most commonly sustained in a match setting ranging between 3 (95%CI:2.4-3.6) and 3.5 (95%CI:2.8-4.3) per round/season without differences between seasons (Figure 3.1B; $p>0.05$). Injury rates in training sessions significantly decreased from 3.0 (95%CI:2.3-3.8) to 1.8 (95%CI:1.4-2.4) to per round/season between 2012/13 to 2017/18 ($\exp(\beta)$ 0.59 [95%CI:0.36-1.0]; $p = 0.04$). Least common injuries resulting in missed A-League matches occurred from ‘other’ settings; with a range between 1 (95%CI:0.5-1.9) and 1.9 (95%CI:1.3-2.7) per round/season. Injury incidences were not significantly different for match and other settings between the 6 seasons ($p>0.05$). However, training injuries were significantly increased in 2016/17 compared to 2012/13 ($\exp(\beta)$ 0.59 (95%CI:0.36-1.0); $p = 0.04$).

When considering the mechanism of injury, non-contact injuries (range; 3.3[95%CI:2.7-4.1]-5.1[95%CI:4.3-6.0] injuries per round/season) were more common in all 6 seasons than contact injuries (range: 1.8[95%CI:1.3-2.4]-2.3[95%CI:1.8-2.9] injuries per round/ season). Although no differences are reported between seasons for contact ($p>0.05$) and non-contact injuries, respectively ($p>0.05$).

The total number of missed matches were 471, 551, 714, 415, 492 and 505 between season 2012/13 and 2017/18. When injuries where categorised into their severity groups, mild injuries significantly decreased (exp(β) 0.64 (95%CI:0.4-0.9); $p=0.02$) and moderate injuries increased (exp(β) 1.7 (95%CI:1.0-2.8); $p=0.04$). Severe injuries were not significantly different across the 6 seasons ($p>0.05$).

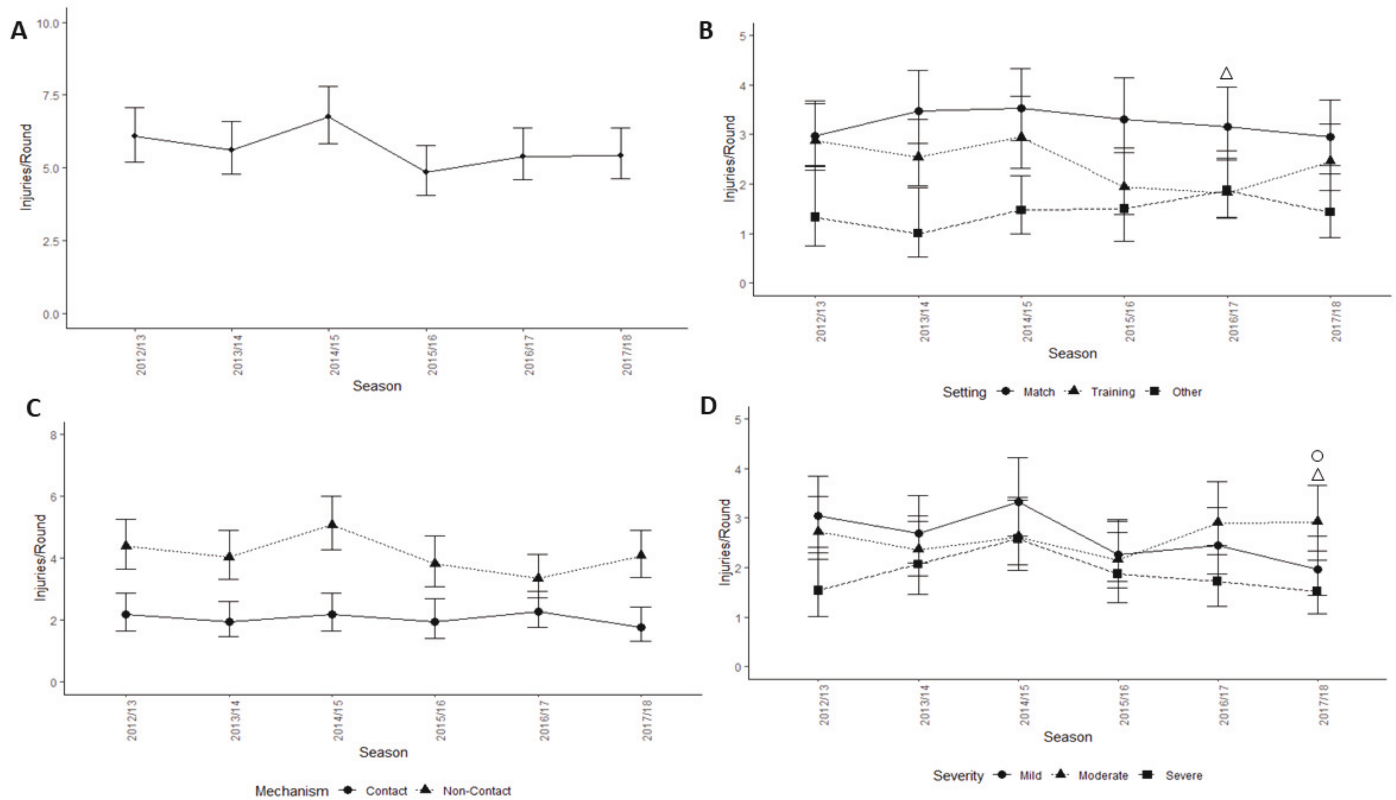

Figure 3.1. Injury trends between season 2012/13 and 2016/17 for A) Total injuries, B) Injuries by Setting, C) injury by mechanism; and, D) injury incidence by severity group.

Figure 1. B) Δ =significantly less training injuries than 2012/13 (p=0.04); Figure 1. D) Δ =significantly more moderate severity injuries than 2012/13 (p=0.004); O = significantly less mild severity injuries than 2012/13 (p=0.02)

The most common location of injury was the thigh (23-36%). From 2012/13 to 2013/14, the second most common injury location was at the hip/groin (16-18%), however, knee injuries were equally the second most common injury in 2014/15 (15%). Knee injuries became second most common injury in 2015/16 (16%) and 2016/17 (16%) followed by lower leg/Achilles Tendon injuries in 2017/18 (16%). There were no significant differences between seasons within each injury location ($p>0.05$; Table 3.1). Subgroups of injury location showed no significant differences between seasons for concussions, which made up 20-75% of all head/face injuries per season. Hamstring injuries (54%-65%) made up the majority of thigh injuries and anterior cruciate ligament injuries made up 14%-29% of all knee injuries. Similarly, Muscle/Tendon (50-60%) and Joint/Ligament (21-34%) injuries were most commonly sustained though, no significant differences are reported between seasons for each injury type ($p>0.05$; Table 3.2).

Table 3.1. Injury count (n), percentage distribution (%), injury rate (95%CI) and rate ratio (RR) by type per season.

	2012/13*		2013/14			2014/15		
Location	N (%)	Injury Rate (95%CI)	n (%)	Injury Rate (95%CI)	RR	n (%)	Injury Rate (95%CI)	RR
Head/Face	5 (3)	1.0 (0.4-2.4)	8 (5)	1.1 (0.6-2.3)	1.1 (0.4-3.8)	2 (1)	1.0 (0.3-4.0)	1.0 (0.1-4.6)
Concussion	3 (38)	1 (0.3-3.1)	4 (57)	1 (0.4-2.7)	1 (0.2-5.1)	2 (14)	1 (0.3-4.0)	1 (0.1-6.0)
Neck/Cervical Spine	0 (0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Shoulder/Clavicle	3 (2)	1.0 (0.3-3.1)	3 (2)	1.0 (0.3-3.1)	0.9 (0.1-6.4)	10 (5)	1.1 (0.6-2.1)	1.1 (0.2-11.4)
Elbow	0 (0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	1 (1)	1.0 (0.1-7.1)	0 (0-0)
Forearm	0 (0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Wrist	1 (1)	1.0 (0.1-7.1)	0 (0)	0 (0-0)	0 (0-0)	1 (1)	1.0 (0.1-7.1)	1.0 (0-36.1)
Hand/Finger/Thumb	0 (0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Sternum/Ribs/Upper Back	2 (1)	1.0 (0.3-4.0)	3 (2)	1.0 (0.3-3.1)	0.9 (0.1-8.5)	0 (0)	0 (0-0)	0 (0-0)
Abdomen	3 (2)	1.0 (0.3-3.1)	5 (3)	1.7 (0.7-4.0)	1.5 (0.2-9.7)	5 (3)	1.0 (0.4-2.4)	1.0 (0.1-11)
Lower Back/Pelvis/Sacrum	12 (7)	1.3 (0.8-2.3)	6 (4)	1.0 (0.4-2.2)	0.7 (0.1-2.8)	17 (9)	1.4 (0.9-2.3)	1.1 (0.2-8.3)
Hip/Groin	27 (16)	1.7 (1.2-2.5)	27 (18)	1.8 (1.2-2.5)	0.9 (0.2-3.1)	27 (15)	1.9 (1.3-2.8)	1.1 (0.2-8.5)
Thigh	37 (23)	1.9 (1.4-2.7)	40 (26)	1.9 (1.4-2.6)	0.9 (0.2-2.8)	43 (24)	2.3 (1.7-3.2)	1.2 (0.2-8.7)
Hamstrings	20 (54)	1.7 (1.1-2.6)	26 (65)	1.4 (1.0-2.1)	0.9 (0.5-1.6)	26 (60)	1.7 (1.2-2.5)	1.0 (0.6-1.9)
Quadriceps/Lateral Thigh	17 (46)	1.3 (0.8-2.1)	14 (35)	1.2 (0.7-2.0)	0.9 (0.4-1.8)	17 (40)	1.2 (0.8-2.0)	0.9 (0.5-1.8)
Knee	25 (15)	1.7 (1.1-2.5)	25 (16)	1.7 (1.1-2.5)	0.9 (0.2-3)	27 (15)	1.5 (1.0-2.2)	0.9 (0.2-6.7)
ACL	3 (14)	1.0 (0.3-3.1)	5 (25)	1.3 (0.5-3.0)	1.3 (0.3-6.1)	6 (29)	1.0 (0.4-2.2)	1.0 (0.3-4.7)
Lower Leg/ Achilles Tendon	20 (12)	1.3 (0.8-1.9)	17 (11)	1.4 (0.9-2.3)	1.0 (0.3-3.5)	22 (12)	1.3 (0.9-2.0)	1.0 (0.2-7.8)
Ankle	17 (10)	1.2 (0.8-2.0)	16 (11)	1.4 (0.8-2.3)	1.0 (0.2-3.6)	24 (13)	1.7 (1.1-2.6)	1.4 (0.3-10.7)
Foot/Toe	12 (7)	1.1 (0.6-1.9)	2 (1)	1.0 (0.3-4.0)	0.8 (0.1-4.5)	4 (2)	1.0 (0.4-2.7)	0.9 (0.1-8.2)

… Table 3.1 Continued

Location	2015/16 n (%)	2015/16 Injury Rate (95%CI)	2015/16 RR	2016/17 n (%)	2016/17 Injury Rate (95%CI)	2016/17 RR	2017/18 n (%)	2017/18 Injury Rate (95%CI)	2017/18 RR
Head/Face	5 (4)	1.0 (0.4-2.4)	1.0 (0.3-3.6)	6 (4)	1.0 (0.4-2.2)	1.0 (0.3-3.5)	5 (3)	1.0 (0.4-2.4)	1.0 (0.3-3.6)
Concussion	2 (20)	1 (0.3-4.0)	1 (0.1-6.0)	3 (75)	1 (0.3-3.1)	1 (0.2-5.4)	5 (50)	1 (0.4-2.4)	1 (0.2-4.9)
Neck/Cervical Spine	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	1 (1)	1.0 (0.1-7.1)	0 (0-0)
Shoulder/Clavicle	1 (1)	1.0 (0.1-7.1)	1.0 (0-11.2)	5 (3)	1.0 (0.4-2.4)	1.0 (0.2-7)	2 (1)	1.0 (0.3-4.0)	1.0 (0.1-8.8)
Elbow	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Forearm	1 (1)	1.0 (0.1-7.1)	1.0 (0-30)	1 (1)	1.0 (0.1-7.1)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Wrist	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Hand/Finger/Thumb	1 (1)	1.0 (0.1-7.1)	1.0 (0-30.4)	1 (1)	1.0 (0.1-7.1)	1.0 (0-29.9)	1 (1)	1.0 (0.1-7.1)	0 (0-0)
Sternum/Ribs/Upper Back	1 (1)	1.0 (0.1-7.1)	1.0 (0-14)	1 (1)	1.0 (0.1-7.1)	1.0 (0-13.6)	2 (1)	1.0 (0.3-4.0)	1.0 (0.1-11.3)
Abdomen	2 (2)	1.0 (0.3-4.0)	1.0 (0.1-8.8)	0 (0)	0 (0-0)	0 (0-0)	0 (0)	0 (0-0)	0 (0-0)
Lower Back/Pelvis/Sacrum	6 (5)	1.2 (0.5-2.7)	0.9 (0.2-4.4)	13 (9)	1.6 (0.9-2.8)	1.2 (0.3-5.1)	6 (4)	1.0 (0.4-2.2)	0.7 (0.1-3.7)
Hip/Groin	10 (8)	1.2 (0.7-2.3)	0.7 (0.2-3.2)	13 (9)	1.2 (0.7-2.0)	0.7 (0.2-2.7)	22 (15)	1.4 (0.9-2.1)	0.8 (0.2-3.3)
Thigh	44 (36)	2.4 (1.8-3.3)	1.3 (0.3-4.8)	43 (29)	2.1 (1.6-2.8)	1.1 (0.3-3.9)	43 (28)	2.1 (1.6-2.9)	1.1 (0.3-4.3)
Hamstrings	27 (61)	1.8 (1.2-2.6)	1.1 (0.6-1.9)	23 (53)	1.4 (0.9-2.0)	0.8 (0.4-1.5)	28 (65)	1.8 (1.2-2.5)	1.1 (0.6-1.9)
Quadriceps/Lateral Thigh	17 (39)	1.4 (0.9-2.3)	1.1 (0.5-2.1)	20 (47)	1.3 (0.9-2.1)	1.0 (0.5-2.0)	15 (35)	1.7 (1.0-2.8)	1.3 (0.6-2.6)
Knee	19 (16)	1.3 (0.8-2.0)	0.8 (0.2-3.1)	23 (16)	1.4 (1.0-2.2)	0.9 (0.2-3.2)	23 (15)	1.3 (0.9-2.0)	0.8 (0.2-3.2)
ACL	3 (19)	1.0 (0.3-3.1)	1.0 (0.2-5.4)	4 (21)	1.0 (0.4-2.7)	1.0 (0.2-5.1)	4 (21)	1.0 (0.4-2.7)	1.0 (0.2-5.1)
Lower Leg/ Achilles Tendon	16 (13)	1.5 (0.9-2.4)	1.2 (0.3-4.9)	14 (10)	1.1 (0.6-1.8)	0.9 (0.2-3.4)	24 (16)	1.7 (1.1-2.6)	1.4 (0.3-5.6)
Ankle	12 (10)	1.1 (0.6-1.9)	0.9 (0.2-3.9)	22 (15)	1.6 (1.0-2.4)	1.3 (0.3-5)	9 (6)	1.1 (0.6-2.3)	0.9 (0.2-4.3)
Foot/Toe	3 (2)	1.0 (0.3-3.1)	0.9 (0.1-5.2)	4 (3)	1.0 (0.4-2.7)	0.9 (0.2-4.6)	13 (9)	1.3 (0.8-2.2)	1.2 (0.3-5.3)

**Reference Group, ACL = Anterior Cruciate Ligament*

Table 3.2. Injury count (n), percentage distribution (%), injury rate (95%CI) and rate ratio (RR) by type per season.

	2012/13*		2013/14			2014/15		
Location	n (%)	Injury Rate (95%CI)	n (%)	Injury Rate (95%CI)	RR	n (%)	Injury Rate (95%CI)	RR
Muscle/Tendon	82 (50)	3.2 (2.5-3.9)	84 (55)	3.2 (2.6-4.0)	1.0 (0.8-1.4)	96 (53)	4.0 (3.3-4.9)	1.3 (0.9-1.7)
Joint/Ligament	53 (32)	2.3 (1.8-3.0)	41 (27)	1.9 (1.4-2.5)	0.8 (0.5-1.3)	52 (29)	2.4 (1.8-3.1)	0.8 (0.5-1.3)
Fracture/Bone Stress	9 (5)	1.5(0.8-2.9)	7 (5)	1.4 (0.7-2.9)	0.9 (0.3-2.6)	12 (7)	1.3 (0.8-2.3)	0.7 (0.3-1.8)
Contusions, Laceration and Skin Lesion	10 (6)	1.1 (0.6-2.1)	8 (5)	1.3 (0.7-2.7)	1.2 (0.4-3.1)	3 (2)	1.0 (0.3-3.1)	0.7 (0.2-2.4)
Central/Peripheral Nervous System	8 (5)	1.0 (0.5-2.0)	7 (5)	1.2 (0.6-2.4)	1.1 (0.4-3.3)	14 (8)	1.1 (0.6-1.8)	0.8 (0.3-2.2)
Other	2 (1)	1.0 (0.3-4.0)	5 (3)	1.3 (0.5-3.0)	1.2 (0.3-8.7)	5 (3)	1.0 (0.4-2.4)	0.8 (0.2-5.6)

… Table 3.2 Continued

	2015/16			2016/17			2017/18		
Location	n (%)	Injury Rate (95%CI)	RR	n (%)	Injury Rate (95%CI)	RR	n (%)	Injury Rate (95%CI)	RR
Muscle/Tendon	67 (55)	2.9 (2.3-3.7)	0.9 (0.7-1.3)	77 (53)	3.0 (2.4-3.7)	0.9 (0.7-1.3)	90 (60)	3.6 (2.9-4.4)	1.1 (0.8-1.5)
Joint/Ligament	26 (21)	1.5 (1.0-2.2)	0.7 (0.4-1.3)	49 (34)	2.5 (1.9-3.2)	1.1 (0.7-1.9)	31 (21)	1.7 (1.2-2.4)	0.6 (0.4-1.1)
Fracture/Bone Stress	5 (4)	1.0 (0.4-2.4)	0.7 (0.2-2.2)	9 (6)	1.1 (0.602.2)	0.8 (0.3-2.1)	15 (10)	1.7 (1.0-2.8)	1 (0.4-2.4)
Contusions, Laceration and Skin Lesion	10 (8)	1.4 (0.8-2.7)	1.4 (0.5-3.6)	3 (2)	1.0 (0.3-3.1)	1 (0.2-3.3)	0 (0)	0.0 (0.0-0.0)	NA (NA-NA)
Central/Peripheral Nervous System	10 (8)	1.3 (0.7-2.3)	1.4 (0.5-3.7)	4 (3)	1.0 (0.4-2.7)	1.1 (0.3-3.5)	10 (7)	1.4 (0.8-2.5)	1.2 (0.5-3.3)
Other	3 (2)	1.0 (0.3-3.1)	1.1 (0.2-8.4)	4 (3)	1.3 (0.5-3.6)	1.4 (0.3-10.5)	5 (3)	1.0 (0.4-2.4)	0.9 (0.2-6.2)

3.5 Discussion

The aim of this study was to quantify the incidence of injuries, setting in which they occurred, mechanisms, types, locations and their severity in Australia's male professional soccer league (A-League). The main finding of this study was that the overall injury incidence remained stable over the most recent 6 consecutive seasons, in part explained by no change between seasons when injuries were categorised by mechanism, type or location. As expected and comparable with European leagues, muscle/tendon injuries of the thigh region were the most common injury type and locations, which also remained stable over the 6 seasons analysed. Further, mild injuries significantly decreased in 2017/18, yet moderate injuries increased in 2017/18 compared to the 2012/13 season. Collectively, injuries over the last 6 seasons in the A-League seem stable at the league level.

Analysis of injury trends can be used to evaluate the effectiveness of injury prevention strategies. The stability of injury incidence rates in the present study is consistent with longitudinal soccer injury epidemiology reported in the UEFA and J-League studies (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011). Specifically, over 15 seasons (1993 to 2007 seasons), injury incidence in the J-League had a gradual, but non-significant decrease ($p=0.118$) (Aoki et al. 2012). Similarly, teams in UEFA competitions also reported overall stable, match and training injury incidence rates between seasons 2001/02 and 2007/08 (Ekstrand, Hagglund & Walden 2011). In the present study training injuries significantly decreased in 2016/17 despite remaining stable across the other seasons. Despite similar season-based trends in the present study, the injury incidence rates are not comparable due to the inconsistent nature of incidence calculation. However, the present data is comparable to the previous A-League results where Gouttebarge & Kerkhoffs (2017) reported an injury count range of 4.7 - 7.4 injuries per 27 rounds between Season 2008/09 to 2012/13. These findings compare favourably to the 4.8 [95%CI:4.6-6.4] to 6.7 [95%CI:5.8-7.8] in 2012/13 to 2016/17 evident in the current study. That said, Gouttebarge & Kerkhoffs (2017) also reported no differences between season injury counts; although, missed matches significantly decreased in the 2 consecutive seasons following Season 2010/11. Reasons for the observed stability are speculative, though in the context of the A-League, Gouttebarge & Kerkhoffs (2017) suggested that the introduction of 'Minimum Medical Standards' by the governing body contributed to a lower number of injuries after 2011, and may further explain the current results. Another suggested hypothesis is the interaction of increasing injurious demands e.g. high-speed running distance, balanced with growing effectiveness of injury prevention strategies (Barnes et al. 2014; Buchheit et al. 2019; Jaspers et al. 2018; O'Brien et al. 2019). Such stability in injury rates following decreased injury trends in 2011/12 highlights the importance of league-wide longitudinal injury surveillance to inform ongoing practice.

This is the first study to present the injury trend per mechanism whereby non-contact injuries were consistently more common in all seasons and stable across 6 seasons. Comparatively, a high proportion of non-contact injuries is consistent with reports from the Hong Kong Premier League over 1 season (Lee et al. 2014), while only 5% of muscle injuries were the result of foul play in 51 European teams (Ekstrand, Hagglund & Walden 2011). It is plausible that injuries are dependent on club circumstances, which may vary significantly between and within clubs e.g. coaching and training style, or provisions for preventative care.

Consequently, between and within club variances should be established to confirm the injury trend and allow clubs to compare between their own seasons and to the rest of the league. It is worth mentioning that all A-League clubs are bound to the MMS. These league-wide standards mandate multiple components of medical infrastructure and medical provisions serviced to teams. In future, knowledge of the injury prevention strategies implemented and/or changed during these seasons would be informative for effective injury prevention practices.

Reporting injury incidence (i.e. number of injuries per period of time) only partially describes the injury situation within a league and can be misleading (Drawer & Fuller 2002b). Thus, reporting injuries with respect to the severity (i.e. resulting missed matches) is important given ensuing match unavailability is associated with team performance (Eirale, Tol, et al. 2013; Hägglund et al. 2013). The current findings show a cumulative range of 415 to 714 missed matches/season, representing a reduction in missed matches reported in previous research on the A-League (Gouttebarge & Kerkhoffs 2017). A reduction in missed matches in the present study is unexpected given the wider inclusion of injury types, although this may be explained by the overall reduction in injury count after 2011/12. Further analysis in the present study reports a decrease in mild injuries, whilst moderate injuries increased over the 6-season analysed. The interpretation of such findings emphasises the dissonance in injury incidence data and requires inclusion of severity to ensure appropriate understanding (Hägglund et al. 2013). That is, despite higher prevalence of hamstrings muscle injuries than anterior cruciate ligament tears, the burden (expressed by days lost due to injury) was 8-fold greater equalling to a similar risk matrix.

Analyses of injury locations and type can guide the development of prevention programs and allocation of resources (van Mechelen, Hlobil & Kemper 1992). Consistent with other professional soccer injury epidemiology research, injuries were most commonly of muscle/tendon type and at the thigh. The proportion of muscle/tendon injuries in the A-League (50-55%) are comparable to the 54% of muscle/tendon injuries in the thigh location reported in a one season injury epidemiology study in the La Liga (Noya Salces, Gómez-Carmona, et al. 2014). In the current study, injury incidences in all locations remained constant across the 6 seasons. Conversely, an annual mean rate increase of 2.3% in hamstring injuries was reported over 13 seasons in 36 UEFA teams until 2014 (Ekstrand, Waldén & Hägglund 2016). The hip/groin location was the second most common site of injury (8-18%) in the present data set. Comparatively, a 15-year study of 47 European teams also reported a decrease in hip and groin injuries by an average of 2% and 3% each season, respectively, despite the burden of both injuries remaining constant (Werner et al. 2019). Novelty in the present findings is the variability of injury locations commonality between seasons, despite all location categories remaining stable across the 6 seasons. That is, the second and third most common injuries varied between hip/groin, knee, lower leg/Achilles tendon and ankle categories without separate linear trends. Longitudinal injury analysis provides context to the differences in the most common injuries; the ankle is the predominant injury location in one season of the Hong Kong Professional League (Aoki et al. 2012). It could be that the league-level injury incidence may erroneously generalise the injury trends, instead, there is high variability between seasons that is not detected by the current methods of reporting. Nonetheless, Between-season injuries analysis should consider variation between locations and include predictive parameters such as workloads mentioned previously for future studies.

Limitations due to methodological differences with previous multi-season league-based injury epidemiology studies should be acknowledged. Differences in reported data of the overlapped season (Season 2012/13) may be due to the different definition and data collection procedures (Gouttebarge & Kerkhoffs 2017). The current study defines an injury if the event missed an official A-League match. Consequence of this definition is the underestimation of injuries with a short severity of less than 5-6 days when playing one match per week. Additionally, recurrent, preseason and off-season injuries were not considered in the injury surveillance. It is therefore difficult to gauge the size of the injury situation, given the influence of previous injury on recurrent injury and importance of training availability for exposure to prophylactic chronic high training loads (Hagglund, Walden & Ekstrand 2006; Windt, Gabbett, et al. 2017). Additionally, training and match exposures were not collected in the injury surveillance system used in this study thus injury incidence per 1000 hours of playing exposure could not be reported. Thus, it is important to remove the confounding effect of different exposure data and limitations of injury definition in collecting injuries to understand the injury risk factors (Cross et al. 2018). Such suggestions will allow Australian male soccer injury epidemiology to be comparable with other leagues and improve accuracy to reflect the state of injuries within the A-League.

3.6 Conclusion

Overall injury incidence rate and injury characteristic injury incidences trends have remained stable over 6 seasons in the A-League. However, training and mild injuries decreased whilst moderate injuries increased. The stability of injuries is coupled with variability in the most common injury locations and types. Findings of the present study demonstrate the most common injuries and injury trends in the A-League, which provides guidance for the injury prevention and treatment of professional male club soccer players.

Chapter 4 : Study 2

Variability of team-level injury underlying league-level injury rates in a professional soccer league

Lu, D., McCall, A., Jones, M., & Duffield, R. Variability of team-level injury underlying league-level injury rates in a professional soccer league. *Journal of Science and Medicine in Sport.* ***In review***

4.1 Abstract

Objective: To describe the variability of team-level injury and relationship with overall, type and location injury rates at the league level in professional soccer. *Design:* Prospective observational cohort study. *Method:* Injury, injury-type and injury-location were collected from all A-League teams (n=10) for 6 consecutive seasons (2012/13 to 2017/18) via a standardised injury surveillance system. Intra-class correlation (ICC) and coefficient of variation (CV) were calculated to assess the between-season variability for each team. Marginal Coefficient of Determination (R^2m) to Coefficient of Determination (R^2c) were then calculated from generalised linear mixed models to determine between season trends, whereby league-, type- and location-injury rates are the response variables, season as the predictor variable and teams as random intercepts. *Results:* The majority of teams had poor to moderate reliability of between-season injury rate (ICC: r=0.319-0.831) and low between-season injury rates variance (CV: 11%-82%). League injury rate in 2015/16 was 0.738 times less than 2012/13 (p=0.011), which coincided with significantly reduced Joint/Ligament injury rates in 2015/16 (p=0.001). The model variance showed the reduction of Joint/Ligament injuries was league-wide (R^2m=0.23; R^2c=0.23). *Conclusion:* Low between-season injury rate variance from most teams contributed to a stable league injury trend apart from a reduction in 2015/16 which Joint/Ligament injury trend mirrored. However, there was no particular influential club, suggesting there was an injury reduction effect at the league-level.

4.2 Introduction

The first step of to preventing injuries is to understand the injury situation to accurately benchmark then later evaluate injury prevention strategies (O'Brien et al. 2019; van Mechelen, Hlobil & Kemper 1992). In professional soccer, injury rate/incidence is the most common measure of an injury situations and can be cross-tabulated by type and location for further detail (Morgenstern 2014; Piantadosi, Byar & Green 1988). Injury rate is often derived by aggregating players into a team or league rate which addresses injury monitoring issues associated with cost and time. Though of concern, previous literature suggests potential fallacies committed when generalising findings between different levels of analysis (Robinson 2009; Wakefield 2009). Given the potentially harmful consequences, it is imperative to have contextual understanding of the variability of team injuries rates that underlie league injury rates; however, the relationship between the two levels of analysis has yet to be understood in professional soccer leagues.

Injury epidemiology studies often assumed that teams within a league are homogenous; ignoring inherent differences in the process of reaching successful performance (Al Attar & Alshehri 2019; Ekstrand et al. 2018; McCall, Dupont & Ekstrand 2018). Hence, generalisations drawn from the league-level may not hold true for teams or individual players (Piantadosi, Byar & Green 1988). Possible volatile trends at the smaller level of analysis i.e. team level injury incidence, may be masked by the stable league-level injury incidence(Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011). However, variability of teams that underlie league soccer injury rates that may provide substantive information has not been investigated (Merlo et al. 2018). Without further contextual understanding of injury rates such as the influence of between season trends of different teams within a league, effectiveness of injury prevention protocols may be misinterpreted (Merlo et al. 2018).

Despite stable injury incidence in a range of professional soccer leagues, recent injury incidence trends reported by injury types and injury locations hint at underlying variability that may not be representative of the league-level injury situation (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011). From the UEFA injury studies, it has been reported that muscle injuries remain stable ($\beta=-0.013$, 95% CI -0.032 to 0.005, $p=0.138$) whilst ligament injuries decreased ($\beta=-0.040$, 95% CI -0.065 to -0.016, $p=0.005$) (Ekstrand et al. 2013). Further, hamstring ($R^2=0.431$, $\beta=1.023$ (95% CI 0.006 to 0.041), $p=0.015$), hip and groin injuries ($\beta=0.98$(95%CI:0.97 to 0.99), $p=0.003$) have increased (Ekstrand, Waldén & Hägglund 2016; Werner et al. 2019). The contradictory injury-specific directional trends oppose the stable overall league injury rates reported (Ekstrand, Hagglund & Walden 2011). Evaluating the trends concurrently may provide understanding on whether teams, as mentioned previously, or the dissection of injury types and location attributed to the stable overall league injury trend.

The accuracy of how injury epidemiology reflects the league-level injury landscape is often overlooked in soccer. Further contextual understanding of injury rates beyond the mean (of injury or clubs) may guide more refined areas of injury concern. Therefore, the aim of this study is to describe the influence of team-level variability on overall league level injury rates, and by type and location over 6 seasons in the Australian professional soccer league.

4.3 Methods

In 6 consecutive seasons of the Hyundai A-League (2012/13 to 2017/18), physiotherapists from each club (n=10) submitted weekly injury data via Football Federation Australia's (FFA) Injury Surveillance spreadsheet to the Injury Surveillance Officer. Each season consisted of 27 matches (October to April) from the professional A-League competition, equating to 810 matches played, during which 421 players sustained 916 injuries. A release of medical records form was signed by each player as part of their A-League contract and permission of data usage was granted by FFA. The study design was approved by UTS Human Research Ethics Committee (UTS REF: ETH18-2324; Appendix A). Compliance to data entry was 100% due to injury surveillance as a legal obligation under the FFA-Professional Footballers Australia Collective Bargaining Agreement for all A-League licenced clubs.

The event of an injury and injury type and location characteristics was recorded in the FFA Injury Surveillance spreadsheet by a medical staff-nominated full-time team physiotherapist. To ensure high reliability of injury data, practitioners liaised with the injury surveillance officer regularly and received written methods and definitions with the injury surveillance proforma that could be accessed at any time. All physiotherapists were to submit injury data on a weekly basis. Injury was defined as '*any physical complaint requiring medical attention resulting in a missed Hyundai A-League match'*. Within the injury proforma, definitions of injury and the categories of type and location was adopted from the F-MARC Injury Consensus Group statement with the Orchard Sports Injury Classifying System – 10 (Fuller et al. 2006; Rae & Orchard 2007). Individual athlete data was summed for each team and season.

All statistical analysis was completed using R Statistical Package with the lme4, sjstats MuMIn (Barton 2009; Lüdecke 2019; Team 2013). To determine the between-season variability of the league injury rate, a subset of the injury data was manipulated into wide format with each team as new variables and season injury rate for each row. The precision and dispersion of team between-season injury rates are assessed using intra-class correlations (ICC) and coefficients of variation (CV), respectively, which were calculated in base R to assess variability. Interpretation of between-season ICC was adopted from < 49% considered as *poor reliability*, >50% indicating *moderate reliability*, >75% is *good reliability*, and >90% is considered *excellent reliability* of the injury determinants (Koo & Li 2016).

Between-season variability coefficients were then paired with coefficients from generalised linear mixed models used to estimate injury rate as the response variable over 6 seasons. Teams were taken up as the random intercepts to explain the model error. Analysis of Covariance was used to compare the full specified models to the null model. Akaike Information Criteria (AIC), degrees of freedom, Chi-Squared and related p-value (alpha at $p<0.05$) was used to assess the fit of the models (Table 4.1). Between-team variability was assessed by comparing the Marginal Coefficient of Determination (R^2m) to Coefficient of Determination (R^2c) to determine the proportion of explained variance with and without specified random intercepts.

A second subset of the data was manipulated so that each injury-type and injury-location are new variables and each row is the season injury rate. Generalised linear mixed models were run where data permitted. Each subset of injury type and location as the response variable, where season was entered as the fixed effect and team as random intercepts.

4.4 Results

Between-season ICCs and CVs calculated for each team are reported in Table 4.1. There were 5 teams where singularity was observed, and ICC could not be computed. As a result, there were 2 teams with poor reliability, 2 with moderate reliability and 1 with good reliability based on between-season ICCs (Table 4.1).

Seven generalised linear mixed models were run for league injury rates, injury type rates and injury location rates; 2 of which were significantly different from null models (Table 4.2). The model whereby league injury rates is the response variable was significantly different from the null model ($p=0.019$) with team injury rates explaining 23% more of the model variance. The model whereby joint/ligament injury rates are the response variable was significantly different from the null model ($p=0.005$); however, random intercepts for teams did not provide any more explanation for the model variance. All other models were not significantly different compared to null models ($p>0.05$; Table 4.2).

Back-transformed coefficients of the two significant generalised linear mixed models identified from likelihood ratio testing in Table 4.2 are reported in Table 4.3. The league injury rate was significantly 0.504 less in 2015/16 compared to season 2014/15 ($p<0.001$).

Similarly, Joint/Ligament injury rates reduced from 18 per team 2014/15 to 12 per team in 2015/16 ($p=0.001$). All other injury type and locations analysed remained stable across the 6 seasons.

Table 4.1. Interclass correlation coefficient (ICC) and Coefficient of Variation (CV) reported for overall injury rates, injury rates by type and injury rates by location.

	ICC (r)	CV (%)
Team		
A	0.831	82
B	-	29
C	0.319	28
D	-	17
E	0.451	40
F	0.610	47
G	0.589	38
H	-	15
I	-	11

Table 4.2. Likelihood Ratio Test comparing full models estimating the overall-,individual type-, and individual location-injury rates over 6 seasons and comparison of marginal (R2m) to conditional (R2c) R-squared.

Model	Df	AIC	Chi-squared	P value (α=0.05)	R^2m	R^2c
Overall Injury Rates						
Null: Injuries ~ 1 + (1 | Team)	2	395				
Full: Injuries~ Season + (1 | Team)	7	392	13.467	0.019*	0.144	0.371
Injury Types						
Null: Muscle/Tendon ~ 1 + (1 | Team)	2	348				
Full: Muscle/Tendon~ Season + (1 | Team)	7	352	6.277	0.280	0.081	0.218
Null: Joint/Ligament ~ 1 + (1 | Team)	2	263				
Full: Joint/Ligament ~ Season + (1 | Team)	7	256	16.974	0.005*	0.233	0.234
Injury Locations						
Null: Hip/Groin ~ 1 + (1 | Team)	2	187				
Full: Hip/Groin ~ Season + (1 | Team)	7	191	5.757	0.331	0.094	0.100
Null: Knee ~ 1 + (1 | Team)	2	188				
Full: Knee ~ Season + (1 | Team)	7	195	1.507	0.912	0.024	0.065
Null: Lower Leg/Achilles Tendon ~ 1 + (1 | Team)	2	169				
Full: Lower Leg/Achilles Tendon~ Season + (1 | Team)	7	177	2.017	0.847	0.031	0.102
Null: Thigh ~ 1 + (1 | Team)	2	251				
Full: Thigh ~ Season + (1 | Team)	7	260	0.491	0.992	0.007	0.123

Table 4.3. Back-transformed coefficients from significant generalised linear mixed models identified from likelihood ratio tests.

Model : Injuries~ Season + (1 | Team)				
Fixed effects:				
	Estimate	Lower CI	Upper CI	P value (α=0.05)
(Intercept)	16.206	13.407	19.424	<2e-16
2013/14	0.927	0.743	1.156	0.499
2014/15	1.110	0.899	1.371	0.333
2015/16	0.738	0.582	0.932	0.011*
2016/17	0.896	0.717	1.120	0.335
2017/18	0.915	0.733	1.141	0.429
Random effects:				
	Groups	Name	Variance	Std.Dev.
	Team	(Intercept)	1.025	1.169

Model : Joint/Ligament Injury Rate ~ Season + (1 | Team)				
Fixed effects:				
	Estimate	Lower CI	Upper CI	P value (α=0.05)
(Intercept)	5.299	3.984	6.860	< 2e-16
2013/14	0.774	0.512	1.160	0.217
2014/15	0.981	0.668	1.440	0.922
2015/16	0.491	0.302	0.776	0.003*
2016/17	1.048	0.711	1.543	0.811
2017/18	0.629	0.397	0.977	0.042
Random effects:				
	Groups	Name	Variance	Std.Dev.
	Team	(Intercept)	1.000	1.022

2012/13 = reference season; * significantly less than 2012/13

4.5 Discussion

This is the first soccer injury epidemiology study to investigate the variability of team-level injury that underlie the overall, by type and by location league-level injury rates. The key findings of this study showed the precision of team between-season injury rates were predominately poor to moderate reliability or unreportable. Although the dispersion of between-season injury rates had low variance reflecting stable league-injury rates, further analysis of multi-factor distribution of injuries of a particular type or location between-seasons identified joint/ligament injury rates concomitantly decreased in the season with reduced overall-league injury rates (2015/2016). However, between-team variance did not explain the error in the joint/ligament model suggesting that the effect was only at the league-level. Together, the findings provide further context that although team differences may attribute to injury trend to a small capacity, it is not enough to reduce injuries across a league.

The present study investigated the precision (ICC) and spread (CV) to understand the team-level variability in league injury rates over the 6 seasons (Merlo et al. 2018). The poor to moderate, even unreportable, reliability of injury rates suggest some team injury rates were stable whilst others varied between seasons. Teams having unreportable ICCs were due to singularity as a result of undifferentiable data, which may be a limitation of the present study (Ellis 2000). Additionally, all teams reported low between-season CVs below 1.0, indicating low variance and that injury rates were not volatile between seasons in each team. Together, the poor ICCs and low CVs of between-season injury rate support the stable injury rate trends across 6 seasons in the A-League. However, it must be highlighted that findings of the present study cannot assume low variance of teams in other league injury epidemiology and warrants analysis of future soccer injury epidemiology with a priori of team differences.

Accurate interpretation of injury epidemiology relies on the understanding of possible fallacy associated with generalising findings across different levels of analysis (Morgenstern 2014). Whilst the ICCs and CVs support stable league injury rates, the R^2m suggests there is limited understanding of ecological effects and bias between levels of analysis (Wakefield 2009). In the current study, the 6 season league injury rates were stable with team differences explaining 23% of the model variance. The contextual understanding of low variability also supports previous multi-team longitudinal studies. For example, in 23 Union of European Football Association (UEFA) teams, injury incidence (i.e. training and match) remained stable at 8.0±3.4/1000 hours of playing exposure (Ekstrand, Hagglund & Walden 2011). From 1993 to 2007, Aoki et al. (2012) reported a league injury rate in the Japanese professional league between 19.11 (16.51-22.01) - 24.37 (21.12-27.99). Neither of the previous studies considered team differences which may influence these trends. The present study suggests inherent differences between teams may be an idiosyncratic factor and generalisation of injury incidences should not be between levels of analyses despite the injury trend remaining stable at both the team and league level.

Cross-tabulation of injuries characteristics can contextualise the injury situation and guide focus of injury prevention (Morgenstern 2014). Although muscle/tendon injuries are the most common type of injury in the A-League, the reduction of joint/ligament injuries decreased significantly in the same season (2015/16) of reduced league injury rate. Comparatively, in the UEFA Champions league studies, Ekstrand et al. (2013) reported stable muscle injuries whilst ligament injuries decreased significantly. However, team differences explained 60% of the aforementioned ligament injury model while team differences did not provide any further explanation to the joint/ligament injuries in the present study. It should be noted Ekstrand et al. (2013) only accounted for difference in the top 4 'core' teams participating in all seasons between 2001 and 2012 (Arsenal FC, FC Internazionale Milano, PSV Eindhoven, and Real Madrid CF) in their multilevel model. The present study suggests there was a league-wide reduction of joint/ligament injuries as opposed to a reduction driven by a single team. This finding may be related to league-wide implementation of injury prevention such as competition rules and regulations. In an earlier injury epidemiology study in the A-League between 2008/09 to 2012/13, Gouttebarge & Kerkhoffs (2017) mentioned that a significant reduction in total injury count was concurrent with the implementation of the 'Minimum Medical Standards', a policy mandating on medical provision and infrastructure within clubs aimed to reduce the number of injuries in the A-league. It may be possible that injuries may have reduced as a result of a change the MMS, however, without analysis this only remains speculative. Nonetheless, a reduction in league injury rate was concomitant with reduced league-wide joint/ligament injuries and should be the focus of injury prevention research and interventions for organisation level stakeholders.

Although the findings provide empirical knowledge for interpreting soccer injury incidence the limitations of the present study need to be acknowledged.(Bahr & Holme 2003) recommended that injury epidemiology requires 20-50 injuries cases to detect moderate to strong associations or 200 injury cases to detect small to moderate associations. The injury rate in this study was 16.2 (95%CI:13.4-19.4) injuries per team per season may not enough to detect differences between teams (Diez Roux 2004). Additionally, the injury definition only captures events that result in missed competitive A-League match which may underestimate the number of injuries particularly of those that occur in training and do not result in a missed match.

The likelihood of ecological bias increases when there is low variability in exposure (Blakely & Woodward 2000; Robinson 2009; Wakefield 2009). That is, the injury exposure in this study was standardised to 27 matches per club in each season resulting in overestimating variability in categories of lower injury rates. Exposure measured by hours and injury incidence reported per 1000 hours of playing exposure would reduce bias and allow for comparable injury incidence to studies following the Fuller et al. (2006) injury epidemiology consensus statement. Additionally, this is a preliminary study of the variability underlying injury rates in professional soccer leagues. Injury burden (i.e. prevalence and severity of injury) was not considered for analysis due to the lack of time-loss due to injury data available in the dataset. As mentioned previously, cross-tabulation of injury events may provide another dimension of reflecting the state of injuries which may hint possible aetiology (Bahr, Clarsen & Ekstrand 2018; Fuller & Drawer 2004). However, injury burden may overestimate injury severity due to this study's match-loss injury definition. Nonetheless, variability underlying injury burden should be considered in future studies using a smaller exposure unit of analysis (i.e. per 1000 hours of playing exposure).

4.6 Conclusion

Accurate interpretation of injury epidemiology is crucial for efficient benchmarking and evaluation of the injury situation in a team or league. The evaluation of league injury variability provides further interpretation of the injury situation as opposed to a limitation of injury epidemiology. In the A-League, stable and volatile team injury trends both attributed to a stable injury trend. A league-wide concomitant reduction of Joint/Ligament injuries league injuries in 2015/16 with overall injuries suggests all teams should prioritise injury prevention.

Chapter 5 : Study 3

The Financial and Performance Cost of Injuries to Teams in Australian Professional Soccer.

Lu, D., McCall, A., Jones, M., Steinweg, J., Gelis, L., Fransen, J. & Duffield, R. The Financial and Performance Cost of Injuries to Teams in Australian Professional Soccer. *Awaiting FFA Legal approval for journal submission.*

5.1 Abstract

Objectives: To determine the relationship between injury incidence, player-salary cost and team performance in the professional Australian soccer league. *Design:* Prospective observational cohort study. *Methods:* Injury incidence, player-salary cost and team performance data were collected from the 10-club Australian A-League competition (n=27 matches/season) over 6 seasons from 2012/13. Player-salary cost of injury was calculated from the salary cap, injury-induced missed matches and player exposure, and trends were reported from generalised linear models. Team performance was determined from league ranking, points, goals (for and against) and match outcome (win, loss or draw) per season and associations with injury estimated from generalised linear mixed-effects models. *Results:* Nine-hundred-and-sixteen injuries resulted in 3148 missed matches. Injury incidence remained stable apart from a decrease in 2015/16 ($p=0.01$). Missed matches were significantly higher in season 2013/14 (55.1[50.7-59.9]; $p<0.01$) and 2014/15 (71.4 [66.4-76.8]; $p<0.001$) compared to 2012/13, without differences between other seasons. Player-salary cost ranged between AUD$187,990-AUD$332,680/team, peaking in 2014/15 ($p<0.01$). Higher injuries rates were associated with additional goals conceded ($p=0.007$). Similarly, sum of missed matches was associated with more conceded goals and drawn matches ($p<0.000$). However, injuries and missed matches were not associated with win-loss records ($p>0.05$, respectively). *Conclusion:* Player-salary cost remained stable concomitant with stable injury rates and missed matches. Despite associations between injury rates and missed matches with goals conceded and matches drawn, the magnitude of these relationships are small. Regardless, injury prevention is important to reduce injury rates and player-salary cost of injuries.

5.2 Introduction

Injury is the most common reason for player unavailability, resulting in a strain on resources for medical care and negative effects on team performance (Parry & Drust 2006). However, the severity of injury and the ensuing impact on club finances are seldom reported; often because comparing data is problematic due to differing league competition models (Bahr, Clarsen & Ekstrand 2018). Additionally, inconsistent findings exist regarding the relationship between injuries and team performance i.e. league ranking, points, goals and match outcome; partly due to previous analyses using single seasons of reduced number of teams analysed (Eirale, Tol, et al. 2013; Hägglund et al. 2013). Thus, further understanding of the effect of injuries on club salary cost and team performance, respectively, can provide further context for decision making regarding injury prevention at a league level. In turn, player salary and team performance cost information can be used as part of a wider reaching multidisciplinary approach to injury prevention and optimal club operations.

Financial stability of clubs and continuity of leagues is grounded in competition success of clubs and minimisation of unnecessary expenditure on unavailable players (Barros, Assaf & de Araujo Jr 2011). Ekstrand (2013) reports the average financial cost for an injured player with a time-loss injury of at least 4 weeks to be estimated at ~€500,000 at elite European levels. However, such information is often gathered through publicly available data, which may over- or under-estimate the financial cost of an injury in professional soccer players. Comparatively, in the salary capped A-League in Australia, the Professional Footballers Australia (2018) report recently outlined a total league salary cost of injury to be AUD$4million. Previous to this report, Gouttebarge & Kerkhoffs (2017) reported a continuous decrease from an accumulated league cost of AUD$6million in Season 2010/11 to AUD$3.3millon in Season 2012/13. Collectively, a lack of reliable continuous data exists at a world setting, whilst current Australian domestic soccer league data is outdated, and thus a more recent player salary cost of injury profile is warranted.

It is not uncommon for team performance to be favourably viewed at the expense of player health and welfare, given injuries may hinder the chance of team success (Hagglund et al. 2013). Injury-induced missed matches resulting in reduced player availability have been shown to be negatively associated with league ranking, number of goals scored and wins accrued in European and Qatari professional football teams (Eirale, Tol, et al. 2013; Hägglund et al. 2013). An 11-year study of 24 Union of European Football Association (UEFA) teams reported that less days lost to injury and greater match availability of players were significantly associated with better league ranking and more points per match (Hagglund et al. 2013). Similarly, in a one season study in the Qatari professional league, lower injury incidence was significantly associated with final league rank (r=0.93), wins (r=0.88), more goals scored (r=0.89) and total points (r=0.93) (Eirale, Tol, et al. 2013). However, none of the latter performance indicators were associated with days lost from injury. In contrast, one team from the French Ligue 1 over 5 consecutive seasons between 2008 and 2013 reported no association between injury incidence and league ranking (Carling, Le Gall, et al. 2015).[9] Indeed, the lack of association may have been due to player availability being high enough within season so that it did not constrain performance (Ekstrand 2013). Accordingly, it is still unclear to what extent reduction in injuries are associated with more successful team performance. Further multi-season, league-wide data is required to have more robust understanding of the relationship between injury incidence and team performance.

Meaningful data on multi-year, league-wide performance and financial costs of soccer injury provides evidence to evaluate the effects of preventative strategies and uphold responsibility of performance optimisation, financial sustainability and athlete care. Therefore, this study aims to describe the player salary cost of injury in the professional Australian soccer league between 2012/13 to 2017/18 seasons. A secondary aim was to determine the relationship of team performance makers and injury in the A-League in those same seasons.

5.3 Methods

Injury epidemiology analysis of 421 players was conducted in the A-League over six consecutive seasons between 2012/13 and 2017/18. Injury data were collected via a standardised Football Federation Australia Injury Surveillance form emailed to a centralised Injury Surveillance Officer weekly from each teams' full-time physiotherapist. The Injury Surveillance Officer collected, collated and analysed the injury data. Quality of injury data was cross-checked with media reporting. Injury data was submitted by each club for all 27 regular season rounds for each season. This equated to 810 matches played by all 10 A-League teams. Submission of injury data was compulsory for all teams as part of the A-League 'Minimum Medical Standards' and thus compliance to injury surveillance was 100%. *Injury* definition was adapted from the Fuller et al. (2006) definition with specific references to A-League matches as *'any physical complaint requiring medical attention resulting in a missed A-League match'*. A player was considered injured until the player was no longer listed as injured. Injury count and injury-induced missed matches was determined from the injury surveillance data for analysis. Each player signed a release of medical records as part of their A-League contract. Approval to use data was provided by Football Federation Australia. The study design was approved by the Human Research Ethics Committee (UTS REF: ETH18-2324).

Salary cap information was collected from the A-League website (A-League 2018), where the data is publicly available, and confirmed internally in consultation with the FFA League Operations department. A conservative estimate of the financial cost of injury each season was calculated by dividing the salary cap by players available and further divided by the rounds played by each team (i.e. 27 rounds) and multiplied by the sum of missed matches as a result of injury, as per the methods established by Gouttebarge & Kerkhoffs (2017)

In order to analyse the relationship between injury incidence and missed matches, and team performance a team's final competition rank, league points, goals (scored and conceded), and the outcome of each match played by a team (win, loss or draw) was obtained. All performance data was collected by Football Federation Australia's League Operations department and accessed through internal databases. League ranking was obtained from a team's final rank upon the conclusion of the regular season. Three points were allocated if a team won, one point if the team drew, and no points for a loss. Data was collected in long format where each row represented a team's data for one season, making the unit of analysis in this study a team's injury and performance metrics throughout one season.

All analyses were conducted in the R statistical language with the packages 'lme4' and 'emmeans' (Lenth, Singmann & Love 2018; Team 2013; Venables & Ripley 2002). To analyse injury, missed matches and player salary cost trends over 6 seasons, three generalised linear models (Poisson with log link) were created. Pre-modelling assumptions were checked, including homogeneity of variance at the *season* level. Separate models were developed with injuries per team, another with missed matches per team and the last with player salary cost per team as the response variable. Season was entered as a fixed variable and likelihood-ratio test compared each full model to a null model. Least-square means of the model coefficients reported the respective average team-injury rate, missed matches and team player-salary cost. Back log-transformation of the injury-model coefficients provided a rate ratio (RR), whereby 1 indicates no change, more than 1 indicated an increase and less than 1 indicates a decrease in rates. Model fits where further checked visually with Quantile-Quantile plots.

To analyse the association between injury and missed matches with team performance variables, two generalised linear mixed effects models (Poisson log-linear model) were developed, one with injury count as the response variable and another with the amount of missed matched as the response variable. Prior to analysis, pre-modelling assumptions were checked, including the presence of homogeneity of variance at the *team* and *season* level, as well as the presence of multi-collinearity. Team performance variables of league ranking, points, goals scored and conceded presented multi-collinearity. Goals conceded had the strongest association with injury and missed matches and therefore was retained for the models. A step-up approach was used by which additional predictors were added to the model with each step, and model fit was evaluated using the Aikaike Information Criterion (AIC), observation of degrees of freedom, distribution of model residuals and comparison of marginal to conditional R^2. Log-transformed injury and missed matches were entered as response variables whilst league ranking, points, goals scored and conceded, and match outcome i.e. win, loss or draw, were entered as fixed predictors, while random intercepts at the team level were introduced to account for the random variance associated with inter-team differences in missed matches or injury counts, and to account for the clustering of team's repeated measures over multiple seasons. Model coefficients were back-transformed to obtain RR's and reported with 95% CI. Model residuals were also obtained and used for a visual inspection of how well the obtained models fit the data.

5.4 Results

Overall count of injuries included for analysis was 916 injuries from 421 A-League players over the six seasons of data collection. The sum of injuries resulted in 3148 missed matches. The absolute number of players training regularly with an A-league team at any one time throughout these six seasons ranged from 18 – 27. As shown in Table 5.1, injury count per team in Season 2015/16 significantly decreased by RR: 0.7 (0.6-0.9) from season 2012/13 ($p=0.01$). Additionally, missed matches per team increased in season 2013/14 (55.1 [50.7-59.9]; $p<0.01$) and 2014/15 (71.4 [66.4-76.8]; $p<0.001$) compared to 2012/13; however, returned to the reference season rate in 2017/18 (50.5 [46.3-55.1]; $p=0.28$). Average player salary cost of injuries per club per season ranged between AUD$187,990 to AUD$332,680 (Table 5.1). Injuries in season 2014/15 showed the highest average player salary cost of AUD$332,680 per team per season ($p<0.01$).

Upon using the step-up approach for the construction of models to explain the variance in injury counts and missed matches as a result of injuries, two final models were retained. The first model consisted of a univariate model in which goals conceded is entered as a fixed effect, injury rate is the response variable and team – injury rate variation is considered with random intercepts (Table 5.2). Back-transformed coefficients from this model demonstrate that injury count and goals conceded were positively associated. The mixed model calculated average injury rate when no goals are conceded is 10.1 (95CI%:7.4-13.8) injuries per team per season and every additional goal conceded was associated with higher injury rates (RR:1.01 [95%CI:1.0-1.02]; Table 5.3).

In the second generalised mixed effects regression model, goals conceded, and draws were retained as fixed effects, with missed matches as the outcome variable and random intercepts at the team level. Back-transformed coefficients obtained from this model's output show a positive association between matches missed and goals conceded. The expected missed matches with no goals conceded was 34.3 (95%CI: 28.7-40.9) missed matches per team per season and additional games drawn showed positive association with higher injury rate (RR:1.01 [95%CI:1.0-1.02]; Table 5.3).

Table 5.1. Profile of injuries per team per season, injury rate ratio, missed matches per team per season and total league salary cap between 2012/13 to 2017/18 used to calculate a financial cost.

	2012/13	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**
Total Injury Count per team per season	16.4 (14.1-19.1)	15.2 (13.0-17.8)	18.2 (15.7-21.0)	12.1 (10.1-14.5)*	14.6 (12.4-17.7)	15.1 (12.9-17.7)
Injury Rate Ratio		0.9 (0.7-1.2)	1.1 (0.9-1.4)	0.7 (0.6-0.9)	0.9 (0.7-1.1)	0.9 (0.7-1.1)
Total Missed Matches per team per season	47.1 (43.0-51.6)	55.1 (50.7-59.9)*	71.4 (66.4-76.8)*	41.5 (37.7-45.7)	49.2 (45-53.7)	50.5 (46.3-55.1)
Salary Cap ($)	2,478,592	2,500,000	2,550,000	2,600,000	2,650,000	2,928,000
Financial Cost of injury per team per season ($)	187,990 (142,713-247,630)	244,853 (192,330-311,718)	332,680 (270,439-409,246) *	188,912 (143,511-248,678)	220,328 (170,817-284,189)	246,927 (194,158-314,039)

*Significantly greater than 2012/13 (p<0.05)

Table 5.2. Retained models that explain the effect of team performance on injury count and count of missed matches.

Model	AIC	df	χ^2	P (α = 0.05)	R^2 Fixed only (%)	R^2 Random + fixed (%)
Null mode: Injury ~ 1+ (1|Team)	395	2			0	27
Injury ~ Conceded + Wins + (1|Team)	392	4	0.009	0.927	10	29
Injury ~ Conceded + Lose + (1 | Team)	391	4	0.689	0.406	11	30
Injury ~ Conceded + Draws + (1 |Team)	392	4	0.418	0.518	11	30
Final model: Injury ~ Conceded + (1|Team)	390	3	7.372	0.007	10	29
Null Model: Missed Matches ~ 1 + (1 |Team)	842	2			0	43
Missed Matches ~ Conceded + (1 |Team)	818	3	20.488	<0.00	24	53
Missed Matches ~ Conceded + Wins + (1 |Team)	819	4	0.598	0.439	26	54
Missed Matches ~ Conceded + Lose + (1 |Team)	819	4	0.871	0.351	25	53
Final Model: Missed Matches ~ Conceded + Draws + (1 |Team)	818	4	13.974	<0.000	27	54

Table 5.3. Back-transformed coefficients, 95% confidence intervals (CI), standard errors and random effects parameters from the 2 final generalised linear mixed models investigating the likelihood of team performance variable are associated with less injuries. Coefficients shown have been back-transformed.

Injury Count				
Fixed Effects				
	Coefficients	Lower CI	Upper CI	Std. Error
Intercepts	10.09	7.39	13.78	1.17
Goals Conceded	1.01	1.00	1.02	1.00
Random Effects		Variance	Std. Dev	
Teams	Intercept	1.018	1.144	

Missed Matches				
Fixed Effects	Coefficients	Lower CI	Upper CI	Std. Error
Intercepts	34.26	28.70	40.90	1.09
Goals Conceded	1.01	1.00	1.01	1.00
Draws	1.01	1.00	1.02	1.00
Random Effects		Variance	Std. Dev	
Teams	Intercept	1.012	1.114	

5.5 Discussion

This is the first study to profile the association between injury, missed matches, player salary cost, and team performance over multiple seasons that include all teams from one domestic competition. Injury and ensuing missed matches remained relatively stable across the six seasons analysed. Similarly, mean player salary cost of injury was also relatively stable, though did spike in 2014/15 to $AUD332,680. From a team performance perspective, injury rate and missed matches showed positive association with more goals conceded. Match wins or loses were not associated with injury or missed matches. However, teams who drew more often appeared to have a higher number of matches missed as a result of injury. In the discussion here, the direction of the aforementioned injury-performance associations has been inversed for more intuitive reading, although it should be noted here that the magnitude of the relationships cannot be inversed in these models. Regardless, these findings show that 1) the player salary cost of injuries remains constant in the A-League alongside relatively constant injury rates, and 2) despite small associations between injury markers and goals conceded by a team, team injury and missed matches were not associated with win-loss performance.

In the A-League seasons prior to the present study (i.e. 2012/13), a peak in player salary cost of injury was reported in 2010/11 at ~AUD$6million, though ensuing reductions were evident to ~AUD$3.3 million in 2012/13 (Gouttebarge & Kerkhoffs 2017). Player salary cost from injury reduced and stabilised (~AUD$2.3million) in this study compared to 5 seasons prior. Stability in player salary cost in the present 6 seasons reflects stability of injuries and ensuing missed matches and was one of the principles of introducing a 'Minimal Medical Standards'. Gouttebarge & Kerkhoffs (2017) suggested the A-League specific MMS that directs club medical provisions and infrastructure may be a factor on reduced injury and player salary costs, and current findings would further support that assertion. Regardless, mean player salary cost due to injury reported here (~AUD$2370,000) is still equivalent to the investment of two A-league player's average yearly salary. Thus, the longitudinal profile of player salary cost of A-League injuries presented here highlights the importance of strategically investing in players resources, particularly in a salary capped league, to budget for injury prevention resources.

Driven by the accumulation of league points, soccer league competition success is ultimately determined by the top-ranked team/s. However, such factors may be hindered by player unavailability due to injury (Eirale, Farooq, et al. 2013). Prior to analysis all performance variables were test for collinearity and removed to avoid inflation of least squares estimators of coefficients as a result of large variances (Mansfield & Helms 1982). Unsurprisingly, multi-collinearity was observed between league ranking, league points and goals scored here, with goals conceded was retained for analysis. Although removed from analysis, the collinearity observed is worthy of discussion. Previously, strong associations were reported in both univariate analyses of injury and league ranking (r=0.93, p=0.003), and injury and points league points accumulated (r=0.93, p=0.003) in one season of the Qatari professional league supporting the linearity noted here (Eirale, Farooq, et al. 2013). Injury-performance associations reported in the Qatari professional league were also observed in UEFA Champions League (Hägglund et al. 2013). Hägglund et al. (2013) reported teams with higher injury burden (i.e. injury incidence and days lost) decreased the likelihood of finishing with higher league ranking (OR:0.99 (95%CI: 0.98-0.10); p=0.011) and more accumulated league points (OR: 0.99 (95%CI: 0.99-1.00); p=0.031).However, it should be highlighted that the magnitude of the aforementioned associations were small. Together, the present and mentioned studies suggest that despite the association the extent of the relationship between injury, missed matches, league ranking and points are small at best.

Number of goals scored and conceded may provide context of a team's ability to be successful in any particular match and may be influenced by injuries (Carling, Le Gall, et al. 2015; Eirale, Tol, et al. 2013). Although goals scored and injuries were not associated, each conceded goal is associated with 1% higher injury rate. That is, teams typically who had higher injury rates at the end of a season also accumulated more conceded goals. The association in this study supports the positive linear relationship between injury rate and number of goals scored (r=0.893, p=007) reported in the Qatari professional league (Eirale, Tol, et al. 2013). Comparably to a multi-season study, there was no differences in goals scored or conceded across 5 seasons for a single French Ligue 1 team (p=0.233 and p=0.994, respectively) despite decreased injury incidence (Carling, Le Gall, et al. 2015). However, differences between the abovementioned studies may arise from different sampling periods and number of teams included for analyses. Another limitation of the former studies is the extent of which conceded goals is related to injury rates is not reported. Of note, confounding factors such as match location, opposition league ranking and period of season were not considered here and should be noted as a limitation of this study. However, despite significant association between goals scored, goals conceded, and injuries reported, the current study suggests that teams with more conceded goals at the end of a season (given the average injury rate is 15 injuries per team per season) only had 0.15 more injuries. Thus, despite the positive association, the magnitude of the effect suggests that the relationship between goals conceded and injury is small.

Winning matches is the fundamental tenant of team performance and remains the primary concern with regards to the insidious effects of injuries. There was no association reported between injury, missed matches and win or loss match outcomes; however, multivariate analysis showed teams with more injury-induced missed matches also accumulated more goals conceded and drawn matches. Similarly, Bengtsson, Ekstrand & Hägglund (2013) reported a positive association between injury and draws, with increased odds of a drawn match compared to a win (OR:1.39 [95%CI:1.15-1.69], p=0.001) when teams sustained two or more injuries. Additionally, 2 or more injuries resulting in more than 1 week absence increased the odds of a match resulting in a draw (OR:2.14 [95%CI:1.69-2.88], p<0.0001) compared to a win (Mansfield & Helms 1982). In contrast, winning teams typically have more shots and more shots on target (Carling, Le Gall, et al. 2015), though once leading, teams shoot less and concede less (Lago-Peñas et al. 2010). Accordingly, given higher injury rates are associated with more goals conceded and more draws, it could be speculated that team defensive style is affected in situations where teams have a goal advantage, thus preventing a winning match outcome (Carling, Le Gall, et al. 2015). However, such conclusions are speculative given player quality and tactical aspects of performance were not considered in the current analysis. Regardless, the current findings show more conceded goals at the end of a season are associated with more missed matches from injury per season, though the magnitude of this relationship is small.

Previous studies have reported generalised relationships between injury and team performance. The current findings do not confirm a strong existence of such a relationship given the rate ratios and confidence intervals suggest uncertainty. However, there are several limitations of the present study that may have contributed to the unclear findings. For example, the impact of player quality unavailable due to injury and squad rotation were not considered in this analysis (Carling, Le Gall, et al. 2015; Dilger & Geyer 2009). It is likely that current analyses without consideration of other factors which may have real impact on injuries and team performance may provide misleading associations and remains of interest for further research.

5.6 Conclusion

In conclusion, this study reports that injury rate, missed matches and player salary cost of injuries in the A-League between 2012/13 and 2017/18 has remained stable. Further, injury is associated with goals conceded whilst missed matches is associated with goals conceded and draws; however, the magnitude of these association is small which may reflect the complexity of successful team performance. Nevertheless, injury prevention is likely important to ensure teams maintain winning advantage within a match and should remain a priority to coaches and competition stakeholders.

Chapter 6 : Study 4

The provision and infrastructure of medical care in professional Australian Professional Soccer Clubs.

Lu, D., McCall, A., Jones, M., Steinweg, J., Gelis, L. & Duffield, R. The provision and infrastructure of medical care in professional Australian Professional Soccer Clubs. *Awaiting FFA Legal approval for journal submission.*

6.1 Abstract

Objective: To examine the provision and infrastructure of medical care and their changes in professional Australian soccer clubs during 4 respective seasons. *Design:* Retrospective observational study. *Method:* All A-League teams in each season (n=10 -11 teams) completed a written survey at the end of 4 respective seasons (2010/11, 2012/13, 2015/16 and 2016/17). The written survey was provided to the Head Physiotherapist in each club at the end of the season and consisted of 11 questions on 1) Experience and Qualifications, 2) Appointments and Time Demands, and 3) Services and Resources in the club. Chi-squared and multivariate analyses were used to report the extent and change in medical department structure, time demands, injury prevention and resources over the 4 seasons. *Results:* For Experience and Qualifications, Physiotherapists typically were tenured for 3.1±2.4y and were postgraduate qualified (55-70%) with experience from other sports (70-91%). For Appointments, teams typically hired 1.6-1.9 physiotherapists, 1.1-1.4 physicians, 1.1-1.3 massage therapists and 1.2-2.0 Exercise specialists each season ($p>0.05$). The Time Demands of practitioners did not differ between seasons ($p>0.05$), except for Exercise Specialists who increased by ≈30 h/week in 2015/16 compared to season 2010/11 ($p=0.014$). For services and resources, injury prevention frequency was daily over the 4 seasons ($p>0.05$). However, an increase in subgroup injury prevention on either a daily or several times/week existed ($\chi2=0.041$; $p=0.005$). All teams completed preseason musculoskeletal screening in all seasons. *Conclusion:* Medical provision and infrastructure has remained similar over 4 seasons in the A-League. However, within the existing infrastructure, an increased emphasis exists within appointed roles to injury prevention.

6.2 Introduction

In elite soccer, backroom staff (i.e. coaches, medical and conditioning staff) are challenged with duty of care for athletes to balance injury risk while optimising performance. Injury trends in many leagues worldwide are reported to be stable (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011), and this stability is tenuously speculated to be a consequence of the increased provision of resources and focus on player health in recent years (Buchheit et al. 2019). Within an Australian context, a stable injury trend has been reported over the last 6 years that also coincided with the implementation of a Minimum Medical Standards (MMS) that dictate the expected services and provision of athlete care (Gouttebarge & Kerkhoffs 2017). For example, mandatory qualified physiotherapist provision at all training and matches. Despite such discourse, limited evidence exists regarding the extent and change in medical service provision in professional football. For example, a personal narrative outlining the growth and extent of staff and equipment existing within Arsenal Football Club to address medical and performance aspects for injuries, recovery, and training represents the closest expose of this state (Lewin & Lewin 2018). Accordingly, investigation into the provision, resources and management of athlete care, and how these have changed over time in professional football, is warranted to better understand and inform the practice of injury risk mitigation in soccer.

Previous literature has reported changes in both the volume and processes of appointing physicians and practitioners over the last two decades in football (Waddington, Roderick & Naik 2001). For example, Malcolm, Scott-Bell & Waddington (2017) surveyed 92 team doctors and 92 team physiotherapists in each English Premiership, Championship and Football Leagues 1 and 2. They reported medical teams consisted of 2.9 doctors and 5.2 physiotherapists per Premier League club, who also reported higher qualifications, greater career-orientation and formalised working contracts (Malcolm, Scott-Bell & Waddington 2017). Similarly, Lewin & Lewin (2018) reported that 30 years on from having only the 1 physiotherapist and 2 part-time doctors, the club as of 2018 included 4 physiotherapists, 1 full-time team doctor and the other support staff such as, masseurs, medical administrator, strength and conditioning coaches and nutritionist. Whilst there seems to be growth in the number of backroom staff, the above accounts only reflect English professional soccer and no literature exists on medical staffing or provision in leagues outside of England.

Given the growth in personnel availability in backroom staffing, a lack of resources and facilities is also identified as a key ecological issue affecting the implementation of athlete care efforts (Donaldson et al. 2019; O'Brien & Finch 2016). In a survey of 500 retired English Professional Footballer's Association players, the club's injury prevention resources and support, such as sport science or education/welfare, were reported to be perceived as inadequate prior to acute and chronic injuries (Drawer & Fuller 2002b). However, the survey was completed almost two decades ago, and the current context of service provision remains unknown as no recent study reports the resources and services available in professional soccer leagues. Accordingly, a more recent outline of the resources and services provided is warranted to identify the barriers and facilitators to develop effective athlete care (O'Brien et al. 2019).

The provision and infrastructure of athlete care and its changes requires further exploration to better understand and inform the practice of injury risk mitigation in football. Therefore, the aims of this study are to identify and outline the changes in 1) Experience and Qualification, 2) Appointments and Time demands, and 3) Services and Resources of athlete care in professional Australian soccer (A-League).

6.3 Methods

An invitation was sent to the Head Physiotherapists of all professional soccer teams playing in the A-League in Seasons 2010/11, 2012/13, 2015/16 and 2016/17 asking them to participate as respondents in the self-administered Medical Review Questionnaire. Questionnaire responses were limited to the abovementioned seasons as a result of data availability from internal Football Federation Australia processes. There were 11, 10, 10 and 10 teams participating the seasons when the questionnaire was administered, respectively. However, there were 11, 9, 10 and 10 questionnaires returned in the 4 seasons, respectively. The Head Physiotherapist from each club was chosen to complete the questionnaire as they have the greatest exposure to the team as a result of mandatory training and match attendance. The questionnaire was developed in Microsoft Word and emailed to the Head Physiotherapist by the Injury Surveillance Officer at the end of each season, along with instructions regarding the purpose and confidentiality of responses. The Head Physiotherapist was given 1 month from the time the questionnaire was sent to complete and return the questionnaire. Partial responses were followed up via email to ensure full compliance.

The questionnaire was originally designed to outline the standard of provision of medical and allied health care in the A-League. The questionnaire was further developed and first piloted with internal FFA medical staff before being disseminated to the clubs. Approval to use the data was provided by Football Federation Australia whilst ethics was retrospectively obtained (UTS REF: ETH18-2324). The questionnaires consisted of 46, 49, 70 and 67 questions per questionnaire in the 4 seasons, respectively. The increased number of questions in the 4 seasons of questionnaires was the result of evolving interest of the FFA Medical Department. There were 11 structured questions consistent throughout the 4 questionnaires which were retained for the purpose of this study to outline the provision of athlete care and the changes over time.

In the questionnaire, the respondents were asked to indicate their previous experiences and qualifications with 3 open questions. The length of tenure in years and months at their current club, name their highest level of qualification relating to role and identify if they had previous experience in other sports. The respondents were dichotomised into either undergraduate or postgraduate level depending on the qualification they stated.

There were 3 open questions regarding the Appointments and Time Demands of athlete care providers. The respondents were asked to mark the number of ‘physiotherapists’, ‘physicians’ and ‘massage therapist’ and the physiotherapist had to mark the professions comprised in their medical staff and indicate their hours of services per week. The respondents were further asked to report physiotherapist time demands into 5 areas – ‘training’, ‘matches’, ‘injury recording’, ‘treating players’, and ‘meetings and communication’. In a separate question, the respondent completing the questionnaire was asked to indicate the number of exercise specialists and how many hours of service to the club by the exercise specialist. An ‘exercise specialist’ was an umbrella term for anyone who was qualified to instruct strength and/or conditioning training sessions such as a fitness coach, exercise physiologist, or sport scientist.

In Services and Resources respondents indicated if injury prevention was delivered in the format of a ‘whole squad’, ‘subgroup’ or ‘individual’. More than one option of injury prevention delivery could be indicated. If indicated, the frequency of the of injury prevention delivery in that particular format was recorded as either ‘daily’, ‘several times a week’, ‘weekly’, ‘more than weekly’, or ‘occasionally’. In a separate question, the respondent was asked to indicate whether musculoskeletal screening was conducted on their team. If it was perceived that musculoskeletal screening was conducted, the respondent indicated if it was completed during ‘preseason’, ‘mid-season’, or ‘end of season’, whereby more than one category could be selected.

All categorical and continuous data was collected in long format with each row representing each season for each team. Assumptions for parametric analysis were checked on the categorical and continuous data. Time demands of physiotherapist and exercise professionals failed a Shapiro-Wilk test for normality. Following visual inspection, these data were log transformed for physiotherapist time demands, though exercise professional time demands remained for analysis. Pearson's Chi-Square test was used conducted to identify significant changes in categorical variables over 4 seasons. Multivariate analysis with Bonferroni post-hoc test was conducted to identify significant changes in continuous variables over 4 respective seasons. Variables were grouped based on categories of 1) Experience and Qualification, 2) Appointments and Time demands, and 3) Services and Resources. The alpha level for all analyses were also set at $p<0.05$.

6.4 Results

The length of Head Physiotherapist tenure was typically 3.1±2.4 years with no significant differences between all seasons ($p>0.05$; Table 6.1). Most physiotherapists had postgraduate qualifications related to sports medicine (55-70%), while the proportion with postgraduate qualifications did not significantly change between seasons ($\chi2=0.627$; $p=0.890$). Additionally, the majority of physiotherapists (70-91%) had experience from other professional sports prior to appointment, without significant differences between seasons ($\chi2=2.150$; $p=0.542$; Table 6.1).

In all seasons surveyed, the number of appointed physiotherapist ($p=0.368$), physicians ($p=0.515$), massage therapist ($p=0.874$) and exercise specialist ($p=0.121$) did not significantly differ (Table 6.2). Whilst the contact time for physiotherapists did not change ($p=0.158$), the allocation of the time spent recording injuries significantly increased in 2016/17 compared to 2010/11 [exp(β):-4.875(-8.706- -1.044); $p=0.007$] and 2012/13 [exp(β):-4.375(-8.413—337); p=0.028]. Physician and massage therapist contact times within clubs did not differ between seasons (p=0.163 and p=0.368, respectively; Table 6.2); however, the Exercise Specialist contact time significantly increased in 2016/17 compared to 2010/11 [exp(β):-30.056(-55.563--4.548); p=0.014].

Table 6.1**.** Mean±SD length of tenure, proportion (%) of undergraduate compared to postgraduate qualifications and percentage (%) of those who had Other Sport Experiences in Head Physiotherapists of each A-league club.

	Season			
	2010/11	**2012/13**	**2015/16**	**2016/17**
Tenure length (y)	3.1±1.6	2.8±2.4	3.5±2.7	3.0±2.9
Only Undergraduate Qualifications (%)	45	44	40	30
With Postgraduate Qualification (%)	55	56	60	70
Had Other Sport Experience (%)	91	78	70	90

Table 6.2. Number of professionals appointed (n) and their time commitments (h) within each A-League medical department in four seasons between 2010/11 and 2016/17.

	Season			
	2010/11	**2012/13**	**2015/16**	**2016/17**
Appointments (n)				
Physiotherapist	1.8±0.4	1.6±0.5	1.9±0.6	1.9±0.3
Physicians	1.2±0.6	1.1±0.3	1.4±0.5	1.3±0.5
Massage Therapist	1.1±0.3	1.3±1.1	1.1±0.6	1.2±0.6
Exercise Specialist	1.2±0.6	1.3±1	1.6±0.5	2±0.9
Contact Time (h)				
Physiotherapist	59±19	65±25	71±23	83±15
Training Attendance	20±6	21±3	25±11	27±14
Match Attendance	5±1	5±1	6±2	6±1
Injury Recording	2±2	3±3	5±3	7±4*, **
Player Treatment	14±7	8±5	10±8	6±4
Meetings and Communication	3±2	3±2	5±3	7±5
Physician	6.3±2.7	5.3±1.9	11.3±10.3	9.7±6.7
Massage Therapist	23.8±22.6	13.2±7.8	20.5±13.8	17.1±11.2
Exercise Specialist	40.5±17.4	48.6±18.1	57.7±27.8	70.6±15.3***

* Significantly greater than 2010/11 (p=0.007)
** Significantly greater than 2012/13 (p=0.028)
***Significantly greater than 2010/11 (p=0.014)

Injury prevention services were delivered as a whole-squad most commonly on a daily basis (18-80%) or several times a week (20-55%); and the proportion of delivery frequencies did not change between seasons ($\chi2=16.562$; $p=0.167$; Table 6.3). The frequency of subgroup injury prevention was significantly more common on a daily or several times per week basis ($\chi2=0.041$; $p=0.005$; Table 6.3). Again, the distribution of individualised injury prevention frequency did not significantly differ over respective seasons ($\chi2=0.163$; $p=0.085$; Table 6.3).

All teams completed preseason musculoskeletal screening in all seasons surveyed. Most teams (54-100%) completed mid-season musculoskeletal screening; however, the proportion of teams who completed musculoskeletal screening during Mid-Season did not differ between seasons ($\chi2=5.863$; $p=0.118$; Table 6.4). The proportion of teams that completed musculoskeletal screening at the end of the season significantly increased from 9% in 2010/11 to 70-84% after season 2012/13 ($\chi2=15.456$; $p=0.001$; Table 6.4).

Table 6.3. Frequency of teams (n) and proportion (%) that completed injury prevention as a whole squad, in subgroups or individuals in four seasons of the A-league between 2010/11 and 2016/17.

	Season			
Frequency (%)	**2010/11**	**2012/13**	**2015/16**	**2016/17**
	n (%)	**n (%)**	**n (%)**	**n (%)**
Whole Squad				
Daily	2 (18)	3 (33)	6 (60)	8 (80)
Several/Week	6 (55)	5 (56)	3 (30)	2 (20)
Weekly	2 (18)	0 (0)	1 (10)	0 (0)
Occasionally	0 (0)	1 (1)	0 (0)	0 (0)
None	1 (9)	0 (0)	0 (0)	0 (0)
Subgroup*				
Daily	1 (10)	0 (0)	5 (50)	4 (40)
Several/Week	4 (40)	1 (10)	2 (20)	3 (30)
Weekly	2 (20)	1 (10)	3 (30)	0 (0)
Occasionally	0 (0)	0 (0)	0 (0)	0 (0)
None	1 (10)	0 (0)	0 (0)	0 (0)
Individual				
Daily	4 (36)	4 (44)	6 (60)	3 (30)
Several/Week	2 (18)	2 (22)	1 (10)	6 (60)
Weekly	0 (0)	1 (11)	2 (20)	0 (0)
Occasionally	2 (18)	0 (0)	1 (10)	0 (0)
None	0 (0)	0 (0)	0 (0)	0 (0)

*Frequency of Subgroup injury prevention implementation was significantly related to Season. p= 0.041.

Table 6.4. Frequency (n) and percentage (%) of teams who conduct musculoskeletal screening in four seasons of the A-League between 2010/11 and 2016/17.

	Season			
Time of Season	**2010/11**	**2012/13**	**2015/16**	**2016/17**
	n (%)	**n (%)**	**n (%)**	**n (%)**
Preseason	11 (100)	9 (100)	10 (100)	10 (100)
Mid-Season	7 (64)	5 (56)	10 (100)	6 (60)
End of Season*	1 (9)	8 (89)	7 (70)	7 (70)

**Teams were significantly more likely to conduct mid-season musculoskeletal screening (p=0.001)

6.5 Discussion

This is the first study to outline the extent and changes in 1) Experience and Qualification, 2) Appointments and Time Demands, and 3) Services and Resources of athlete care in professional Australian soccer (A-League). The key finding of the present study is that there has been a greater time devoted within appointed roles to injury prevention; as demonstrated by greater time demands for exercise specialist, musculoskeletal screening at the end of the season and injury prevention delivered in subgroups.

The introduction of injury-focussed practitioners within sport environments is considered integral to the maintenance of athlete health alongside performance optimisation (Dijkstra et al. 2014). Time employed in a role builds experience and exposure, and in the A-League the tenure of the head physiotherapist was 3.1±2.4y. Such a duration compares favourably with the English Premiership, Championship and Football Leagues 1 and 2, where the tenures of head doctors and physiotherapists are 1-5 years (Malcolm, Scott-Bell & Waddington 2017). Comparatively, coaching staff have shorter tenures than club doctors and physiotherapists given coaches in the A-League had tenures of 2.1±1.3 seasons. Thus, the longer tenure of the head physiotherapist suggests knowledge and familiarity with the players and club is valued; though given the lower pay salary than coaches, it may allow for greater job security (Orchard 2009). Currently, no information on why doctors or physiotherapists terminate their employment or contract exists; hence, an understanding of the reasons for support staff turnover remain speculative.

Returning athletes to play requires specialised knowledge of the relevant sport demands and the pathology of injuries (Scott & Malcolm 2015). Hence, it is unsurprising that the head physiotherapists were more likely postgraduate qualified and had prior experience in other high-performance sports. Given the highly competitive niche of physiotherapy in a 10-11 team League, being both qualified and experienced is assumed as a more attractive candidate for employment. Although not collected here, English rugby and soccer reported appointment processes of medical practitioners were typically informal, i.e. recruitment regardless of qualifications or experience (Malcolm 2006; Waddington, Roderick & Naik 2001). More recently, doctors and physiotherapists working in professional English soccer report being interviewed before appointment; however, the interviewers were not always qualified to judge the medical professional expertise (Malcolm, Scott-Bell & Waddington 2017). Despite highly qualified and experienced physiotherapists working within Australian soccer, the quality of provision of athlete care cannot be assumed and requires further investigation.

Advancing technologies and practices to measure performance and knowledge of injuries has created space for new professions and working dynamics in sports medicine and backroom departments (Reid, Stewart & Thorne 2004). In the current study, the volume of staff appointed into physiotherapist, doctor, massage therapist and exercise specialist were unchanged over the 4 seasons analysed. Lewin & Lewin (2018) previously outlined that these roles have been well integrated into the soccer environment for more than 2 decades and perceived as an integral component of athlete care. In addition, within each A-League team it can be expected that 2 physiotherapists would be employed or contracted by clubs, with at least one at full time capacity, working alongside a sports physician, massage therapist and exercise professional (i.e. sports scientists, strength and conditioning coaches and exercise physiologist). The practitioners available for A-League players is expectedly less than the 2.9 doctors and 5.2 physiotherapists per English premier league club (Malcolm, Scott-Bell & Waddington 2017). Considering the ratio of practitioner to players, it is expected with larger squad sizes in the English Premier League will require more practitioners (23 in A-League v 25 in English Premier League). The type and volume of appointments suggest that multidisciplinary backroom staff is valued and well-integrated in Australian professional soccer. However, there is no evidence to suggest that such disciplines work together, nor is it known that an integrated multidisciplinary treatment plan is more beneficial compared to disciplines working in silos (Rago et al. 2019).

Barnes et al. (2014)reported that modern soccer matches have evolved to be more physically demanding, requiring more pragmatic training to optimize performance. The time demands of exercise professionals, such as strength and conditioning coaches, exercise physiologist or sport scientist have significantly increased in 2016/17 compared to all seasons prior. A cross-sectional survey study reported athlete access to multidisciplinary teams is viewed as very important (42.2%) and somewhat important (27.5%) by 393 athletic trainers (Arvinen-Barrow & Clement 2015). The current study is the first to report on the appointment of exercise professionals in professional soccer environments, making comparison to other research on sports medicine departments difficult. However, the change in the demand of exercise professionals may reflect the increased professionalism of exercise practitioners in soccer. Lewin & Lewin (2018) reported that a high-performance department was only introduced in 2014 for an elite English Premier League club, and thus the introduction of new professions is likely to be related to the effect of new match and training monitoring technology. In soccer environments, measurements using i.e. Global Positioning System (GPS) and heart rate monitors are partially responsible for the increased demands on these professions. In Australian soccer, exercise specialist involvement is becoming greater, likely driven by attempting to meet the increasing physical demands of the game whilst minimising injury risk.

Compliance, adherence and ability to execute injury prevention tasks are essential aspects that are also barriers of reducing the risk and incidence of injury (McCall, Dupont & Ekstrand 2016). The current survey showed a majority of teams complete injury prevention programs on a daily basis through a whole-squad approach. However, the proportion of teams who delivered tailored injury prevention to subgroups increased, suggesting teams are individualising injury prevention programs within their logistical constraints (Tee, McLaren & Jones 2019). It is known that injuries have multiple temporal risk factors that do not act in isolation (Bittencourt et al. 2016). Hence, targeting injury risk factors with a comprehensive injury prevention programs is imperative (Buckthorpe et al. 2019). Delivering injury prevention to individuals may require resources that are too consuming for a team, and thus separating squads into groups with similar risk profiles or positions may be most appropriate method to individualise injury prevention interventions. A limitation of the current survey question on frequency of injury prevention provision was that it was not followed up with questions on the kind of injury prevention program implemented (Fortington et al. 2015). Regardless of injury prevention implementation, the effectiveness is limited to the engagement of the coaches and players to adhere to the program, perform exercises correctly and progress appropriately. However, information regarding the adherence, quality and adaption to injury prevention programs was gathered in the present study.

Injuries have a dynamic, recursive nature resulting in an ever-evolving profile of injury risk leading to the greater implementation of musculoskeletal screening methods (McCall et al. 2014; Meeuwisse et al. 2007). In the A-League, all teams completed pre-season musculoskeletal screening that was likely to be repeated during the season. Conversely, end-of-season increased in the latter seasons surveyed. Similarly, in 33 UEFA elite clubs, 94% of teams completed musculoskeletal screening whilst 87% performed it continuously in the pre- and in-season (McCall et al. 2014). The increase in end-of-season screening may be the result of developments in theoretical understanding of injury risk factors to be dynamic and temporal (Bittencourt et al. 2016). Whilst musculoskeletal screening is argued to be beneficial for preventing injuries directly, there are perceived benefits from screening to early identify health problems, particularly related to previous injuries, as secondary injury prevention strategy (Bahr 2016; van Dyk & Clarsen 2017). As a result, Australian clubs seem to take similar proactive approaches to reducing injury

A major contextual factor to this study is the implementation of MMS in the A-League. As mentioned previously, the injury trends significantly decreased from 202 injuries after 2010/11 season before stabilising between 121-182 injuries per season (Gouttebarge & Kerkhoffs 2017; Study 4). Gouttebarge & Kerkhoffs (2017) mentioned that the injury decreases after 2010/11 coincided with the implementation of the MMS. The MMS became mandatory for the 2011/12 A-League season with the intention to reduce injury. The MMS may have contributed to similar standard of medical provision and infrastructure in all 4 seasons surveyed. Without drawing association between injuries and medical department structures and resources, it is plausible that sufficient medical provision and infrastructure is not a causal factor but rather addresses some confounding effects of injury to individual players. Conversely, the effect of inadequate provision and infrastructure of athlete care is limited by the MMS. Another limitation is the bias from the physiotherapist perspective. Whilst the physiotherapist has the most contact time with the players, other staff and club, they were considered as the most appropriate person to complete the questionnaire. However, in the results of this study are reliant on the backroom staff knowledge of other roles and responsibilities, which is not realistic if disciplines act separately. Hence it highlights that the responses provided by the physiotherapist are perceptions of athlete care from backroom staff within their club.

6.6 Conclusion

The provision of athlete care is both the duty of clubs and a necessity to ensure players have the potential to perform at their optimum. In the A-League, appointment and role demands of backroom staff has remained similar over the 4 seasons surveyed. Of the physiotherapists who were appointed, they were typically postgraduate qualified and had previous experience in other sports. All clubs implemented at least daily injury prevention program and pre-season musculoskeletal screening. Over the seasons, time demands of exercise specialist increased, individualising of injury prevention programs and more frequent musculoskeletal screening. In conclusion, the provision and infrastructure has remained similar over 4 seasons; however, there has been greater emphasis on injury prevention amongst backroom staff.

Chapter 7 : Discussion

7.1 Introduction

The adverse effects of injuries on the success and competitiveness of teams, as well as individual player welfare is of ongoing concern for sporting organisations and the leagues they oversee (Arliani et al. 2014; Hägglund et al. 2013; Vann Jones, Breakey & Evans 2014). The current thesis undertook a novel assessment of professional soccer injuries in Australia from a league-wide perspective to aid decision-making by stakeholders on athlete care. As such, this thesis examined the incidences of injury over 6 seasons (2012-13 to 2017-18) and the concurrent provision and infrastructure of athlete care in the A-League. Understanding these two components can assist efforts towards the reduction of injury incidence and improve health and safety of athlete participation and performance.

Accordingly, the primary aims of this thesis were;

1. Determine the incidence of injuries and injury characteristics in the A-League and analyse the trend of injuries over a 6-season period (Study 1).
2. Examine the league- and team-based variability in league injury rates in the A-League over 6 seasons (Study 2)
3. Examine the financial and performance cost of injuries in the A-League over 6 seasons (Study 3).
4. Profile and identify changes of the provision and infrastructure of medical care in professional A-League soccer clubs in 4 seasons (Study 4).

7.2 Injury epidemiology of Australian professional soccer players

7.2.1 League- and team-level injury rate and trends

Injury epidemiology can be used to evaluate the effectiveness of injury prevention strategies and drive modifications to the intervention or injury prevention foci (van Mechelen, Hlobil & Kemper 1992). This thesis builds from the analysis of A-League injury epidemiology first reported for Seasons 2008/09 to 2012/13 (Gouttebarge et al. 2017) and extends in scope and duration to Season 2017/18. In Chapter 3 (Study 1), the league-level injuries in the A-League ranged between 4.8 [95%CI:4.6-6.4] to 6.7 [95%CI:5.8-7.8] injuries per round and remained stable between 2012/13 to 2017/18. Compared to the previous A-League data, this study shows comparable A-League injury rates reported for 2008/09 to 2012/13, with between 4.7–7.4 injuries per round and were also stable suggesting that the stable trend is influenced by the MMS (Gouttebarge et al. 2017). Of note, comparison of these two A-League studies are limited to differences in data collection methods based on type of injury collected. Such a stable trend is comparable with the J-League (mean match-loss injury incidence rate: 21.77/1000 player hours; $p=0.118$) and UEFA league teams (mean time-loss injury incidence rate: 8.0 ± 3.4/1000 player hours; $p>0.05$). In contrast, injury trends in Norwegian professional league over 6 seasons reported that although acute injuries increase 49%, the increase was not stable (Bjørneboe, Bahr & Andersen 2014). Given these studies are the only longitudinal data currently available, the current study further confirms stability in injury rates in multi-season league-based data; however, may fluctuate between seasons. Accordingly, it seems regardless of the injury definition, injuries remain stable.

Despite stable league-level injury rates, Chapter 4 (Study 2) reports there is low variance in between-season injury rates at league-levels, and such injury rates are likely to reflect team-injury rates. Wider epidemiological studies have identified mathematical fallacies which can arise from aggregation of data that may impact accurate interpretation of injury trends. Chapter 4 (Study 2) attempts to understand the two levels i.e. team- and league- level analysis by assessing the variability of team level injury trends that underlie the league- level trend. Prior to mixed modelling, low between-season CVs (<1.0), and low variance suggests injury rates at the team level reinforce the stable league-level injuries reported in Chapter (Study 1). Currently, this is the first study to report this finding, as no such data is reported in the J-League or from the UEFA team injury trend (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011).

Accounting for team differences revealed injuries significantly reduced in Season 2015/16 compared to 2012/13 ($p=0.011$), which coincided with a significantly reduction of joint/ligament injuries ($p=0.003$). Comparably, Ekstrand et al. (2013) reported 60% of the model variance with a downward trend of ligament injuries in a 27-team study between 2001 and 2012 when accounting the differences between the 4 'core' and the rest of the teams. The 4 'core' teams (Arsenal FC, FC Internazionale Milano, PSV Eindhoven, and Real Madrid CF) are historically considered successful clubs that may grant the affordance of sufficient provision and infrastructure to implement injury prevention without barriers of resources access. In the A-League, team differences may be less pronounced due to a closed system format and salary cap attracting players of similar calibre (Dabscheck 2011). While teams may be an idiosyncratic factor as opposed to an injury risk factor, it may capture a myriad of factors that may indirectly effect injury incidence and trends. Hence, Chapters 3 (Study 1 and

4 (Study 2) confirm the validity of the injury trends in the A-League, highlighting stable trends at both the team- and league- level. Agreement between the levels of analysis support that any policy or decision making applied from FFA in 2015/16 of the A-League influenced all clubs, rather than idiosyncratic responses from individual clubs. What this policy or implementation was remains speculative and will be discussed later in this chapter. In future, assessment of the team variability and use of multi-level modelling should be adopted to ensure interpretation of injury trends are appropriate.

7.2.2 Type and Location injury rate and trends

Longitudinal cross-tabulated analysis of injuries provides considerable context to the differences, or lack of, in the most common injury types and locations; and in turn allows an accurate insight of injuries within a league (Morgenstern 2014). Characterising injuries by location and type can assist in prioritising a plethora of injury risk factors and guide the development and allocation of resources for prevention programs. Chapter 3 (Study 1) used the Fuller et al. (2006) consensus statement categories to characterise injury location. The common injury locations in the A-League are at the thigh (23-36% of total injuries) which is consistent with reports from European and Asian leagues (Noya Salces et al. 2014, Lee et al. 2014, Ekstrand et al. 2009, Aoki et al. 2012). Of thigh injuries in the A-League, hamstring injuries (53-65%) were more common than quadriceps injuries (35-47%). League-wide studies commonly report hamstring and quadricep injuries collectively in complying with the Fuller et al. (2006) consensus statement. However, hamstring injuries (48.1%) were more common than quadricep injuries (29.6%) in 84 Italian professional soccer players over one season (Corazza et al. 2013). The slightly higher proportion of hamstring injuries may be due to the consideration of adductors in the ‘thigh’ category. The frequency of thigh injuries seems logical given the physical demands of soccer include high power-based eccentric loads from lower body movements particularly resulting from running (≈20-30% of injury mechanisms) (Wong 2005). However, caution is advised when interpreting the frequency of hamstring injuries, which commonly have short lay-off times as reported in UEFA studies, of which the FFA Injury surveillance injury definition may grossly underestimate (Esktrand et al. 2016).

Injury trends can be more meaningful in contextualising the injury risk. In Chapter 3 (Study 1), hamstring injuries were the most common, followed by variation between hip/groin, knee, lower leg/Achilles tendon and ankle categories. However, there were no significant differences between the 6 seasons for these injury locations. The stable between-season variation in all seasons (Chapter 4; Study 2) demonstrates the importance of describing injury trends to better understand injury patterns. From the UEFA injury study, it has been reported that hamstring injuries increased by 2.3% per year over 13 seasons in 32 European clubs (Ekstrand, Waldén & Hägglund 2016). The high rates of hamstring injuries are not uncommon given the demands of sprinting and high intensity running loads placed on the hamstring in football (Barnes et al. 2014). However, reasons for the contrast of stable hamstring injuries in Australia and increasing rates in Europe are unknown and speculative. A plausible reason may be due to the engagement in prophylactic hamstring injury exercises that are possibly more common in Australia. Table 2.1 shows injury prevention is mandatory in Australia, whilst issues of poor compliance continue to be reported from European cohort hamstring injury prevention studies (Bahr, Thorborg & Ekstrand 2015). That said, a survey study of 44 Premier League clubs reported 65.9% of all clubs used Nordic exercises to prevent non-contact injury (McCall et al. 2014). However, without evidence confirming injury prevention practices of all clubs in each league such reasons remain speculative. Regardless, understanding injury location is informative than injury incidence rates alone to lead to better allocation of injury prevention resources (Bahr, Kannus & Van Mechelen 2003).

Muscle/tendon injuries (50-55% of total injuries) were the most common type of injuries, followed by joint/ligament injuries (21-34% of total injuries) in the present A-League studies. Comparatively, in 23 UEFA teams muscle/tendon injuries made up 35% of all injuries whilst ligamentous injuries were about 18% of all injury types (Ekstrand, Hagglund & Walden 2011). Similarly, in Hong Kong Professional League, muscle injuries made up 29% of injuries, whilst ligamentous injuries were 28% of all injuries (Lee et al. 2014). The lower proportion of injury types in the European study and the Hong Kong Professional League may be due to the differences in the categories of injury used. That is, whilst both studies used the OSICS categories recommended by Fuller et al. (2006), Lee et al. (2014) omitted nerve, synovitis/effusion and overuse injury categories. Such difference highlights precaution needed when comparing injury types and calls for future studies surveillance for all injury types. Nonetheless, regardless of the methodological difference, muscle/tendon injuries are the most common injury types and will require prioritisation for injury prevention.

In the present thesis, the A-League injury trend for ligament injures remained stable since 2011/12, except for 2015/16 season when joint/ligament injuries showed a league-wide reduction. Accompanying this joint/ligament injury trend was the lack of explained model variance from team-level data, which suggests there was a league-level effect. This was not the same in European soccer, where consideration of team differences explained 60% of the estimated injury trend (Ekstrand et al. 2013). The fact that team difference was accounted for in both studies may be the reason why the UEFA Injury Studies reported similar injury trends for muscle/tendon and joint/ligament injuries. That is, Ekstrand et al. (2013) reported stable muscle injuries ($\beta=-0.013$, 95% CI -0.032 to 0.005, $p=0.138$) whilst ligament injuries decreased significantly ($\beta=-0.040$, 95% CI -0.065 to -0.016, $p=0.005$). The results further show an inverse relationship between the league- and team- level joint/ligament injury trend thus hinting at ecological fallacy. Such a finding is of concern as inappropriate interpretation at the incorrectly level of analysis may lead to misinformed decision making by the governing body. Regardless, the major injures of concern, being the reduction in joint/ligament injuries, responded favourably though an explanation is currently unknown. Further research is required to profile the events before, during and after the reduction to better understand any underlying causes.

7.2.3 Circumstances of injury occurrence

In senior professional male soccer players, the rate of injury in matches is typically greater than in training (Ekstrand, Hagglund & Walden 2011); however, few studies have reported this injury context over time. In the A-League, match injuries were also more frequent than in training. However, the A-League injury incidence rate is not comparable to the match and training injury rates reported in other existing match and training injury analyses due to calculation discrepancies (Jones et al. 2019; Muaidi 2019). That is, the denominator of the injury rate was taken by rounds played in the A-League season as opposed to hours of exposure used in recent research (Hopkins et al. 2007). Beyond the injury rate, A-League training injuries significantly decreased in 2016/17, despite remaining stable across the other seasons. Comparatively, the match ($\beta=-0.015$, 95% CI -0.032 to 0.003, $p=0.093$) and training ($\beta=0.000$, 95% CI -0.035 to 0.034, $p=0.988$) injury trends between 2001 and 2012 remained stable across the 11-season analysis in 27 UEFA teams (Ekstrand et al. 2013). It should be noted that stability may be influenced by the aggregation of injuries. Ekstrand et al. (2013) further reported an annual decrease in match and training injury rates by 2.3% and 0.9% per season, respectively, when using a 2-year moving average approach and accounting for team differences. Regardless of the professional league, the rate of injury is higher in match then training which may be related to precaution in taken in training to avoid injury (Larruskain et al. 2018; Reis et al. 2015). However, in the A-League the higher match injuries may be related to the injury definition. That is, the match-loss definition may have underestimated injuries from training situations which is a limitation of this thesis (Aoki et al. 2012). Accordingly, interpretation of injury characteristics should be undertaken with context of the injury definition and methods of calculation.

Despite, soccer being officially labelled as a non-contact sport, it does carry an inherent risk of injuries occurring from both contact and non-contact mechanisms. In the A-League between 2012/13 to 2017/18, the proportion of non-contact injuries to contact injuries were greater; however, the proportion of non-contact injuries did not differ between seasons ($p>0.05$) (Chapter 3; Study 1). Comparatively, a high proportion of non-contact injuries is consistent with reports from the Hong Kong Premier League over 1 season (Lee et al. 2015), while only 5% of muscle injuries were the result of "foul play" in 51 European teams (Ekstrand et al. 2011). Conversely, in 91 English premier and football leagues, 39% of sprain injuries were the result of non-contact mechanisms (Ekstrand et al. 2013). In explanation of these findings, the majority of non-contact injuries have been reported to result from running-based actions (López-Valenciano et al. 2019; Wong & Hong 2005). These running-based actions, consisting of high eccentric loads, are often suggested as key mechanical risk factors in injury development (Arnason et al. 2008; Greig & Siegler 2009; Rahnama et al. 2003; Timmins et al. 2016). Such risk factors are plausibly dependent on club circumstances, which may vary significantly between and within clubs e.g. coaching and training style, or provisions for preventative care (Ekstrand et al. 2018). Thus, league-wide injury reduction strategies may be related to competition policy or a league-wide injury prevention programs given league-wide policies are not regularly changed (Vouillamoz 2016).

7.2.4 Severity of injury

Reporting injuries with respect to the severity (i.e. resulting missed matches) adds another dimension to assessing injury priority, and is important given ensuing match unavailability is associated with team performance (Bahr, Clarsen & Ekstrand 2018). Injury-induced missed A-League matches significantly increased in 2013/14 and 2014/15 ($p>0.05$) (Study 1). In the five seasons prior, Gouttebarge & Kerkhoffs (2017) reported that the collection of hamstring, groin, knee and ankle injuries resulted in a peak of 202 injuries resulting in 1110 missed matches in 2010/11 before reducing significantly to 166 injuries resulting in 760 missed matches in 2011/12 ($p<0.05$). The reduction in missed matches may have been driven by the peak of 78 knee injury incidents resulting in 424 missed matches in 2010/11 and subsequently, halved to 35 knee injuries resulting in 2.6 times less missed matches (n=162) in 2011/12 (Gouttebarge & Kerkhoffs 2017). Whilst the A-League injury rate in 2013/14 and 2014/15 seasons did not vary, missed matches significantly increased ($p>0.05$). It could be that there were fewer injuries with that were more severe in these seasons which may be an oversight of using a one-dimensional measure to assess injuries. However, Chapter 3 (Study 1) showed between 2012/13 to 2017/18 mild injuries decreased ($p=0.02$) whilst moderate injuries increased ($p=0.04$) in the A-League. In explanation, less frequent injuries can still have a big impact on player unavailability. Bahr, Clarsen & Ekstrand (2018) suggest a matrix of injury burden (i.e. injury occurrence and missed matches) is more informative of the behaviour of injury patterns. Such a method would allow for better representation of injuries that are low frequency with severe consequence such as concussion to be considered in policy development. Whilst the prevalence of injury is an important measure, there may be more value for clinicians to understand the severity of the injury which may give additional context to return to play timeframes.

To summarise Section 7.2, league-level injuries in the A-League between 2008/09 and 2017/18 remain stable. The stability of league injuries between 2012/13 to 2017/18 was also observed when characterised by type, location and mechanism. However, team-level injury incidence trends showed a reduction of joint/ligament injuries in Season 2015/16 which was league-wide and was enough to notice an overall injury reduction. The severity of an injury offers another dimension to measure injury which may be more informative, though has been reduced in the A-League. The studies from this thesis demonstrate limitations of the injury definition and calculation of injury rate; however, injury trends aid appropriate interpretation to guide and influence league-wide policies for player health.

7.3 The impact of injuries on Australian professional soccer

7.3.1 Financial repercussions of injury

The financial cost of injuries impact clubs in the affordance of players, resources and ongoing sustainment of clubs and leagues (Késenne 2000). The A-League follows a closed system format with no promotion/relegation and a maximum of 23 players rostered within a salary cap (A-League 2019). In the A-League since 2008/09, league player-salary cost of injury peaked in 2010/11 at ~AUD$6million which reduced to ~AUD$3.3 million in 2012/13 (Gouttebarge et al. 2017). Following 2012/13, mean A-League player-salary cost per team per season peaked at $332,680 which coincided with 47.1 (43.0-51.6) missed matches per team per season in 2012/13, significantly increasing to 71.4 (66.4-76.8) missed matches per team per season in 2014/15 ($p<0.05$). The spike in player salary cost is due to the calculation of the financial cost factoring missed matches. In 2013/14 and 2014/15 missed matches significantly increased to 55.1 (50.7-59.9) and 71.4 (66.4-76.8), respectively (Chapter 5; Study 3). The spike in missed matched is likely temporally aligned with fluctuations in all injury characteristics (Chapter 1; Study 1), in turn explaining the spike of missed matches and ensuing costs in 2013/14 and 2014/15. Regardless, the player-salary cost of injury is a conservative measure of the financial cost on clubs that reflects 13% of the salary cap in 2014/15. This financial cost is limited in reflecting the ensuing medical care cost of ~AUD$2.3million, which is the equivalent investment of two A-League player's average yearly salary. Despite the recent reduction of financial cost of injury, it still highlights the importance of strategically investing in player injury prevention resources, particularly in a salary capped league.

7.3.2 Performance repercussions of injury

Multiple studies have identified an association between injuries in soccer and other football codes resulting in player unavailability and team success (Eirale, Tol, et al. 2013; Hägglund et al. 2013; Williams et al. 2016). Injury-induced missed matches are associated with league ranking, number of goals scored, and wins accumulated from univariate analyses reported in European and Qatari professional football teams (Eirale, Tol, et al. 2013; Hägglund et al. 2013). The abovementioned association support the multi-collinearity found between league ranking, league points and goals scored here, with goals conceded was retained for analysis in this thesis (Chapter 5; Study 3). In the A-League, injury and missed matches were also associated with goal conceded and matches drawn; however, the back-transformed coefficient showed that the magnitude was small. It was observed in Chapter 5 (Study 3) that A-League clubs between 2012/13-2017/18 had a 1% higher injury rate for every goal conceded relating to (given the average injury rate is 15 injuries per team per season) only 0.15 more injuries. Hägglund et al. (2013) reported associations between injury, injury burden, player unavailability final league ranking ($p=0.386$,$p=0.015$,$p=0.037$, respectively) and points per league match ($p=0.026$, $p<0.001$, $p<0.001$, respectively); though conclusions were made from interpretation of the p-values rather than back-transformed coefficients. When the coefficients reported by Hägglund et al. (2013) were back-transformed (i.e. exponentiated) the magnitude was also 1%, which supports the small associations between injury and team performance reported in study 3. Nonetheless, the findings from this thesis provide context that injuries may influence a team's ability to be successful in any particular match but not over a season, and that the resulting relationships are small.

7.4 Provision and infrastructure of athlete care in professional Australian soccer

Elite club practitioners are often in the frontline of maintaining athlete health alongside performance optimisation (Buchheit et al. 2019; Dijkstra et al. 2014). Chapter 6 (Study 4) surveyed the experience and qualification of each head physiotherapist in each A-League Club over 4 seasons. These results showed there was no change to supporting medical infrastructure; however, within professional roles there has been a greater emphasis on injury reduction protocols. The following will discuss the injury and injury prevention situations concurrently which may provide clues to why injuries and/or ensuing financial and performance costs significantly change in certain seasons.

7.4.1 Experience and qualifications over time in the A-League

In the A-League the tenure of the head physiotherapist was 3.1±2.4y which is comparable to the 1-5 years of tenure of head doctor and physiotherapist in the English Premiership, Championship and Football Leagues 1 and 2 (Malcolm, Scott-Bell & Waddington 2017).

Head doctors and physiotherapists tenures are typically longer than the 2.1±1.3 seasons average of coach tenure. The contrast highlights the value of placed on knowledge and familiarity of physiotherapists with the players and club (Orchard 2009). Within the context of the A-League, the MMS requires all teams to have physiotherapist coverage at all training sessions and matches. It is likely the league demand for the physiotherapist role ensures more reliable job security, adding to plausible reasons why tenure of physiotherapists was would be longer compared to other team officials (Orchard 2013). However, it is important to highlight that appointment processes and reasons for termination of contract was not examined so no comments can be made regarding the reasons for this finding.

In the A-League, there were more postgraduate qualified and experienced head physiotherapists compared to undergraduate and non-experienced or not experienced outside of soccer. In the A-League, practicing physiotherapist are required to be registered with the Australian Health Practitioner Regulation Agency. Registration requires practitioners to be qualified most via formal tertiary education. Sports physiotherapy is a highly competitive niche branch of physiotherapy, particularly in Australia where the no promotion/relegation A-League competition allows only for 10-11 elite soccer teams. It could be assumed that being more qualified and experienced provides a more attractive candidate to appoint. Comparatively, from a questionnaire completed by physiotherapist working English Football between 1997 to 1999, only half of the physiotherapist were chartered (Waddington, Roderick & Naik 2001). Although a more recent study conducted another questionnaire regarding appointments, qualification of physiotherapists were not followed up (Malcolm, Scott-Bell & Waddington 2017). Further, low variance in team injury rates existed between seasons and stable injuries across the 6 seasons of the A-League (Chapter 4; Study 2) together with the unchanged qualification standard in physiotherapists. It is too speculative to link these findings, but regardless of highly qualified and experienced physiotherapists working within Australian soccer, it does not necessarily associate with better athlete care and requires further investigation.

7.4.2 Appointment and time demands over time in the A-League

Allied health professionals are generally considered responsible for the provision of care and support for injuries in clubs and considered a key component to team success (Ekstrand 2013). The volume of A-League team staff appointed into physiotherapist, doctor, massage therapist and exercise specialist roles were unchanged over the 4 seasons analysed. Within each A-League team it can be expected that 2 physiotherapists would be appointed by clubs, with at least one at full time capacity, working alongside a sports physician, massage therapist and/or exercise professionals. Comparatively, the provision of doctors and physiotherapists are less than in English premier league clubs (Malcolm, Scott-Bell & Waddington 2017). That said, squad sizes are larger in the English Premier League (23 in A-League v 25 in English Premier League). Although the type and volume of appointments suggest that multidisciplinary teams are valued and well-integrated in professional soccer, it does not reflect the emergence of sports medicine in soccer. Lewin & Lewin (2018) outlined the appointment of allied health professionals, other than a physiotherapist, occurred in Arsenal Football Club with full time massage therapists as early as 1996. It may be that sports medicine by 2012/13 is a well adopted component of performance, and thus no change no further noticeable advancements have been observed.

In the A-League, exercise professionals (i.e. strength and conditioning coaches, athletic trainer, exercise physiologist, sport scientist, etc.) involvement is becoming greater, likely driven by attempting to meet the increasing physical demands of the game whilst minimising injury risk (Soligard et al. 2016; Windt & Gabbett 2017). Specifically, the time demands of A-League exercise professional's roles have significantly increased in 2016/17 compared to the previous 3 seasons of surveys. The increased demand of exercise professionals may reflect the increased roles of exercise practitioners in soccer as a result of wearable technology i.e. Global Positioning System (GPS) and heart rate monitors. In 2015, the International Football Association Board permitted the use of Electronic Performance and Tracking System devices allowing a comprehensive understanding of match and training physical loads to be tracked and managed (FIFA 2015). The wealth of data has led to greater research of the relationship between workload and injury aetiology (Lu et al. 2017; Windt & Gabbett 2017). Exercise professional involvement may very well be positively effective given modern soccer matches have become more physically demanding (Barnes et al. 2014). Though practices implemented by exercise professional practices limit the effect of hazardous physical loads. On the contrary, the requirements of the exercise professionals within the A-League have not changed since the inception of the A-League MMS. It could be speculated the involvement of exercise professionals beyond the minimum requirement had no additional benefit or is not enough to see any benefits. However, there is no evidence to suggest the role of exercise professionals is associated with injuries and such speculation requires further investigation

7.4.3 Services over time in the A-League

The provision of services for athlete welfare is difficult to implement in professional club situations as a result of scheduling for training, match, and other sponsorship or promotional obligations. Between Seasons 2010/11 to 2017/18, the majority of A-League teams completed whole-squad injury prevention programs on a daily basis. Whilst whole group injury prevention is typically delivered as a comprehensive program, there is little evidence to show they are effective (Fanchini et al. 2020). Throughout the seasons surveyed in Chapter 6 (Study 4), A-League teams have supplemented their whole-squad approach with more individualised injury prevention programs within their logistical constraints. Such approaches have also coincided with injury aetiology research calling for more risk factor targeted injury prevention (Buckthorpe et al. 2019). That is, the current understanding of injuries is that they have multiple temporal risk factors that do not act in isolation (Bittencourt et al. 2016). Hence, a comprehensive injury prevention program targeting multiple injury risk factors is thought to maximise preventive efforts (Buckthorpe et al. 2019). However, identifying and prioritising the plethora of injury risk factors and providing resources for individual athletes in a team sport environment may be too consuming for a team. Thus, the delivery of injury prevention in subgroups based on position or risk profiles may be more feasible in the A-League and is represented by this change over time in injury prevention program use.

Despite the lack of predictive value of musculoskeletal screening, it is continuing to be a popular protocol completed to mitigate injury risk or identify performance weaknesses

(McCall et al. 2014). Whilst musculoskeletal screening in the preseason and during the season remained of similar use, more clubs started to screen at the end of the season 2017/18. Similarly, 94% of elite UEFA teams completed musculoskeletal screening whilst 87% performed it continuously in the pre- and in-season (McCall, Dupont & Ekstrand 2016). The comparable results suggest that pre-season and in-season screening is now the industry norm. The increase in exercise professionals time demands may have facilitated musculoskeletal testing which may not have been practical before exercise professionals were appointed. However, the increase in end-of-season screening may be the result of greater understanding of the ever-evolving profile of injury risk requiring more frequent musculoskeletal screening (Meeuwisse 2007; Bahr 2016; Bittencourt et al. 2016). The frequent implementation of musculoskeletal screening and yet the stable injuries may suggest that screening is completed for more a physical performance perspective rather than injury mitigation.

7.5 The state of affairs of injury in Australian soccer

Of the provisions and infrastructure of athlete care in the A-League, there has been greater emphasis on injury prevention with more frequent musculoskeletal screening and shift towards individualised injury prevention programs. A major factor to the provision and infrastructure of athlete care in the A-League is the implementation of the MMS. Gouttebarge et al. (2017) noted the reduction in injuries after 2010/11 coincided with the implementation of the MMS and speculated a causative association, though no evidence exists to date to support this theory. Although this thesis does not explicitly explore this speculative association, it does provide further context to understand of the injury situation of Australian professional league soccer. Whilst inherently speculative, the following section explores the epidemiology, impact and provision and infrastructure of athlete care within the context of the A-League MMS; including its changes and other notable events that may have influenced the A-League injury rates and types.

In Australian soccer, doctors, physiotherapists, and exercise professionals were included in the A-League MMS since being implemented (A-League 2011) and there are hints of a cultural shift towards valuing allied health staff in 2014. In the 3rd version (2014) of the A-League MMS it was specifically stated that *"the Club Doctor is an integral part of each League Club and is ultimately responsible for the health of League Players whilst in the League Club environment"* (A-League 2014, pg. 1). In 2016, version 5 of the A-League MMS ethical issues were addressed with the statement "*A decision made by the Club Doctor regarding the health of an A-League Player must not be overruled by the technical staff of an A-League Club*" further emphasising the importance and value of allied health providers in Australian soccer (A-League 2016, pg. 1). Whilst the culture shift has been outlined in professional soccer (Lewin & Lewin 2018), there is minimal research to understand the dynamics and full benefits of multidisciplinary treatment plans compared to disciplines working in silos (Rago et al. 2019). Nonetheless, the consistent and directed attitudes towards medicine and medical support in Australian soccer positively coexist with the observed stable injury trends.

In the A-League throughout 2012/13 to 2017/18, the injury trend remained stable with a transient reduction in 2015/16 season. Within the season of reduced injury, the 5th version of the A-League MMS had multiple additions including the mandating of *'evidence-based and industry accepted'* injury prevention programs. Although a pragmatic approach to injury prevention may be more effective, there is ambiguity in the types of injury prevention programs that are 'industry accepted'. Additionally, no data is available to suggest if and what kind of *evidence-based and industry accepted* injury prevention was undertaken. However, the mandating of such practice in league policy is of importance, alongside the increased time devoted by staff to injury reporting and prevention programs (Chapter 6; Study 4). Nevertheless, the A-League injury trend returned to the average injury rate after the significant reduction of injuries in 2015/16. Whilst admittedly speculative, it may be that the emphasis of *'evidence-based and industry accepted'* injury prevention programs was diluted with the regular turnover of practitioners and further changes of the MMS. Auditing of the mandatory items of the A-League MMS may offer a solution to understand if evidence-based and industry accepted programs were adhered to, if indeed they were used at all. Regardless, mandating evidence-based and industry accepted programs addresses implementation issues dependent on coach leadership style limiting to program adherence, quality of exercise performed and appropriate progression (Ekstrand 2018; O'Brien et al. 2019).

As part of evidence-based injury prevention programs, the benefits of musculoskeletal screening have been extensively debated (Bahr 2016; van Dyk & Clarsen 2017). In Studies

2 and 4, the injury data shows that joint/ligament injuries reduced in the same season anterior cruciate ligament screening was introduced. Anterior cruciate ligament screening was added to the A-League MMS in the 5th version of the A-League MMS (effective from 2016). Though not suggesting causation, the obligatory anterior cruciate ligament screening provides context that an increased focus existed concurrently with the league-wide reduction of joint/ligament injuries in 2015/16. Whilst Bahr (2016) demonstrated that pre-screening tests do not have any clinical value in predicting an injury, van Dyk & Clarsen (2017) suggest that pre-screening tests are still useful in early detection of health problems. It could also identify physical strength and weakness has led to further devotion of strengthening surrounding and support structures of the anterior cruciate ligament as part of training. Again, without further information the association of reduced injuries and the implementation of anterior cruciate ligament screening is speculative. Future analysis on joint/ligament injury trends and musculoskeletal trends can confirm if such relation exists.

Compliance, quality and access to resources to execute injury prevention tasks are essential aspects that are also barriers of preventing injury (McCall, Dupont & Ekstrand 2016). It is plausible that sufficient medical provision and infrastructure is not a causal factor but rather addresses some confounding effects of injury to individual players (Schwartz 1994). Hence the implementation of the A-League MMS with reasonable mandated items has been necessary for protecting players regardless of their club. Theoretically, it can be expected that injury prevention programs may be effective if given the right environment. Regardless, and appreciating the speculative nature of this section, the MMS continues to be enforced in the A-League and ensures practitioners are proactive in athlete care. The MMS also continues to be reviewed by medical staff, scientist, and administrators to ensure the policies are specific to soccer in Australia. Future prospective research investigating the relationship between the MMS and injury is warranted.

7.6 Limitations

While the current thesis examines the injury epidemiology and the injury prevention situation in the Australian professional soccer league, there are a number of identifiable limitations that need to be considered. Firstly, methodological differences with previous multi-season league-based injury epidemiology studies should be acknowledged (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011; Gouttebarge & Kerkhoffs 2017). Few soccer injury epidemiological studies were comparable to A-League injury epidemiology as a result of discrepancies in injury definition (an injury if the event missed an official A-League match). Comparatively, the Fuller et al. (2006) consensus statement on soccer injury definitions and data collection procedures states an injury is "*Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss from football activities*" (pg. 97). It should be acknowledged that the injury surveillance system used to collect injury data for studies 1, 2 and 3 has existed prior to the Fuller et al. (2006) consensus statement. It should be also acknowledged that a consequence of the match-loss definition includes the underestimation of injuries with a short severity of less than 5-6 days when playing one match per week, such as training injuries not resulting in a missed match. Additionally, recurrent, preseason and off-season injuries were not considered in the injury surveillance (though will be captured in future injury surveillance). Therefore, the size of the injury situation is difficult to gauge, given the influence of previous injury on recurrent injury and importance of training availability for exposure to prophylactic chronic high training loads (Windt et al. 2017; Hägglund, Waldén & Ekstrand 2006). That said, the injury trends are still valuable in evaluating the injury situation and injury prevention in Australian soccer. As the FFA Injury Surveillance data collect continues, remedies addressing the limitations of the system continues to be implemented.

Standardised surveillance systems are important in allowing comparison of findings with other studies. Throughout this thesis direct comparisons have been made with the findings from Gouttebarge et al. (2017) as a precursor to the current analyses. However, in this study time-loss injury and missed matches data was collected without a standardised method via multiple publicly available sources and only for hamstring, groin, knee and ankle injuries. The surveillance system used by the current thesis was mandated through the MMS where an injury surveillance officer ensured accuracy of data entry and compliance managers ensured clubs submitted injury data. Of note, the differences in standardised and non-standardised data collection are noticeable in the overlapped season where Gouttebarge et al. (2017) reported a total of 162 injuries whilst Study 1 reported 164 injuries inclusive of all injury locations and types. Hence studies 1, 2 and 3 provide a baseline injury rates for future comparison.

Another limitation of the studies in this thesis is training and match exposures were not collected in the injury surveillance system. In the current thesis, injury rate is expressed per season made up of 27 rounds which is consistent throughout the study period. The low variability also leads to possible ecological bias (Wakefield 2009; Robinson 2009; Blakely & Woodward 2000). That is, overestimating injury rates in categories of low injury prevalence such as upper limb injuries or concussions. Exposure measured using a smaller exposure unit of analysis (i.e. per 1000 hours of playing exposure) would allow for comparable injury incidence to studies following the Fuller et al. (2006) injury epidemiology methods consensus statement. However, it should be noted that current injury surveillance methods of A-League injuries now collect training and match exposures. A repeated study updating A-League injury trends should be reported as both injury rate per 27 rounds and injury incidence per 1000 hours of exposure to ensure data is comparable to both previous A-League season and to other professional soccer leagues.

Finally, this thesis presents a novel approach to injury prevention throughout a sporting organisation by identifying whether injury prevention existed at a team or league level and provides an example of effectively regulating reasonable club practices. However, without consideration of other factors such as training load data, musculoskeletal data or further details of injury prevention programs adopted which may have impact on injuries and team performance (Windt & Gabbett 2016; Buckthorpe et al. 2019). Addition of the aforementioned factors could provide multi-level understanding of individual athlete and team level injury risk factors; however, in the present remains of interest for further research.

Chapter 8 : Summary, Practical Applications and Future Directions

8.1 Thesis aims

Stable injury trends have been reported in previous multi-team injury epidemiology studies (Aoki et al. 2012; Ekstrand, Hagglund & Walden 2011); though methodological epidemiological differences make comparison and introspection difficult i.e. definitions, calculation and data collection procedures. Recently, the Asian Football Confederation, of which Football Federation Australia is a member, called for more Asian soccer injury epidemiology given the absence of such data (Eirale, Farooq, et al. 2013). However, providing only a description of the injuries may lead to shortcomings when developing effective injury prevention programs Bahr, Clarsen & Ekstrand (2018) . It is important to describe how injuries impact performance and on clubs financially to elicit multi-level stakeholder interest (Ekstrand et al. 2017; Garcia-del-Barrio & Szymanski 2009; Høigaard, Jones & Peters 2008). Further, understanding the injury prevention situation is imperative so barriers of injury prevention can be address in the development of effective strategies.

This thesis provides a detailed description of the prevalence and impact of injuries and the provision and infrastructure of athlete care within the professional Australian soccer league. Specifically, Chapters 3 (Study 1) and 4 (Study 2) examined the injury trends at the league- and team- levels of analysis and outlined the injury trends reported by injury characteristics (i.e. mechanism, type, location and setting. Accordingly, Chapter 5 (Study 3) examines the ensuing player-salary cost of injury and team performance effect of injuries. Thus, findings from Chapters 3 (Study 1), 4 (Study 2) and 5 (Study 3) provides a multidimensional understanding of A-League injuries which may have implications for influential stakeholders such as the head coach/manager who is concerned with winning and competition organisers who are concerned with the sustainability of the league. In response to this gap in the literature, Chapter 6 (Study 4) outlined the provision and infrastructure of athlete care throughout the A-league. By examining the provision and infrastructure of care across a league at 4 time points over a 7-season period, the minimum standard of care, infrastructure and resources was described; in turn assisting with evaluation of policies, and guide practice from an organisational standpoint. Hence, these findings have implications for administrative decision-making, resource allocation and injury prevention strategies at the national federation and league level.

8.2 Key findings

The key findings delivered from this thesis are:

Study 1:

- League-level overall (i.e. match and training) injuries remained stable between 2012/13 and 2017/18 which continues the stable trend in the seasons prior to this analysis.
- The most common injuries were at thigh, of which the majority were muscle/tendon type hamstring injuries. League-level injuries remained stable across the seasons by type and location.
- Although stable injury trends were observed, mild severity injuries decreased whilst moderate severity injuries increased.

Study 2

- Agreement between league- and team- level injuries is supported by low variance and poor to moderate intra-class correlation between-season injuries within each team. The poor to moderate reliability and low variance between-seasons for each club supports the stable team-level injury rates with the exception of 2015/16 when injuries reduced.
- There was a transient reduction of team-level injuries in 2015/16 which coincided with team-level joint/ligament injuries. The model variance showed the reduction of joint/ligament injuries were due to a league-wide effect rather than the influence of a single or a few teams.

Study 3

- Player-salary cost remained stable between AUD$187,990-AUD$332,680/team, with a peaking 2014/15 ($p<0.01$). The injury cost trend is concomitant with stable injury rates and missed matches.
- Despite associations between injury rates and missed matches with goals conceded and matches drawn, the magnitude of these relationships are small; thus, team performance is more complex than injury occurrence alone.

Study 4:

- Medical provision and infrastructure of athlete care has remained similar over 4 seasons in the A-League although there was greater time demands for exercise professionals.
- Within the existing infrastructure there has been an increased emphasis on mitigating injury risk. There was more frequent and targeted injury prevention, musculoskeletal screening, and time spent on recording injuries.

8.3 Practical applications

Some of the practical applications that may be delivered from this thesis are:

- Resources should continue to be allocated to prevent non-contact muscle/tendon training and match injuries at the thigh particularly the hamstring in the A-League.
- Although most common injury types and location are of interest for stakeholders, competition organisers and medical staff should still be aware of the variation in less common injuries.
- Hierarchical models generalised linear mixed models in sports injury epidemiology accounting for team differences may provide benefits of injury epidemiology for all levels of analysis and identifying where an injury prevention effect came from.
- Longitudinal profiling of player-salary and team performance costs of A-League injuries highlights the need to strategically investing in players to budget for injury prevention resources.

- A Minimum Medical Standards policy may be necessary for competitions to control injuries. Additionally, continuous injury surveillance and auditing of provision and infrastructure of athlete care is necessary to identify the most appropriate and effect practices.

8.4 Future Research

Recommendations for future research related to the findings from the current thesis should look to examine:

- A repeated A-League injury epidemiology considering comparable injury definition that captures injuries regardless of missed match and collect exposure data at a small unit of analysis i.e. hours of exposure. Additionally, collection of injuries within the Fuller et al. (2006) injury definition is necessary if the surveillance is to withstand changes to competition or to compare with other professional soccer leagues. It should be acknowledged that a change of definition will not necessarily result in lost historical data, rather 2 sets of statistics can be reported.
- In 2015/16, a league-wide reduction of joint/ligament injuries resulted in an overall reduction in injuries. Further research is required to understand the cause of the transient reduction of injuries. The present thesis hints an association between injuries and the provision and infrastructure of athlete care in the A-League, future research should investigate such a relationship.
- No injury risk factors were modelled with injury in the present thesis. Future research should identify risk factors and confounding factors that may affect injury risk.

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Appendices

Appendix A – Ethics Approval

HREC Approval Granted - ETH18-2324

Research.Ethics@uts.edu.au
Thu 7/06/2018 4:47 PM
To: alan_mccall@yahoo.co.uk <alan_mccall@yahoo.co.uk>; Rob Duffield <Rob.Duffield@uts.edu.au>; Donna Lu <Donna.Lu@uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

Thank you for your response to the Committee's comments for your project titled, "Injuries in Professional Australian Soccer; a League-Based Analysis of Trends, Influences and the Cost of Injuries.". Your response satisfactorily addresses the concerns and questions raised by the Committee who agreed that the application now meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. ETH18-2324.

Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://remote.uts.edu.au , and click on "RM6 - ResearchMaster Enterprise" after logging in.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Associate Professor Beata Bajorek
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
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REF: E38