Injuries in Australian Rules Football: A Review of the Literature

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Abstract

Background:

Australian Rules Football is one of the most popular sports in Australia. Successful injury prevention relies on injury surveillance to establish the extent of injuries, to monitor injury patterns and to evaluate prevention strategies. Despite the popularity of participation at the community level, few injury surveillance studies have been published, so a detailed review of the literature is vital. There is limited information available outside of the elite level. Injury statistics for any professional sport may not necessarily be translatable to community sport level.

Objective:

To document the most prevalent injuries at the elite, junior elite, amateur and junior level and determine if incidences differ across levels of play. Aetiology and significant risk factors for injuries are emphasized and prevention and treatment discussed.

Discussion:

Injuries on average are more common at the elite level compared with other levels of participation. The type of injury varies slightly, with non contact injuries, particularly muscle strains, being the most common. Of these, the hamstring strain is the most common. Aetiology and risk factors vary between levels of play due to a time basis, physical development, speed of play and skill level. Recurrence rates are a concern for clubs and players, although rates are decreasing at the elite level, indicating better treatment and conservative management of injured players.

Key Words

Australian Rules Football, AFL, injuries.

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Introduction

Data describing Australian Rules Football injuries have predominantly come from injury surveillance studies from the professional Australian Football League (AFL) (comprising the fewest participants in this sport[1]). There is limited information from hospital emergency departments, sports practitioners, surveys or surveillances from the amateur and junior level. One of the difficulties in documenting the prevalence of injuries and comparing study findings has come from defining an injury. The AFL injury survey, which has been conducted annually since 1992 (the last 6 seasons with 100 per cent compliance[2]), defines an injury as any physical or medical condition that causes a player to miss a match in the regular season[3]. Injury definitions and methods have a very strong influence on the injury incidence reported by studies[4]. The AFL's definition reduced the tendency of team recorders to interpret injury definitions subjectively. Administrative records of injury payments to players who did not play matches determined the occurrence of an injury[3]. It is somewhat controversial, because by taking into account only injuries that cause matches to be missed, it is argued that not all minor injuries are reported[3-5] and it may discriminate against pre-season and finals injuries[3]. The injury survey is publicly released making it one of the world's leading injury surveys[2].

Australian Rules Football is a unique sport played on natural grass. There are 18 players per team on the field, with four players for an unlimited interchange bench[6]. The field is oval in shape and the size varies between 135 metres and 185 metres in length and between 110 metres and 155 metres in width[6]. Each game is played continuously for 80 minutes plus stoppage time[6] and involves running, sprinting, tackling of the player in possession of the ball and kicking[7]. The primary means of ball progression is the drop punt kick, performed on both left and right sides[8].

When performing a drop punt kick, quadriceps acts eccentrically in the wind up phase and then concentrically in the forward swing phase[8]. Hamstrings acts concentrically to initiate back swing and eccentrically in follow through[8]. There is little difference measured by EMG between left and right foot kicks[8]. High EMG activities are read in the kicking leg's quadriceps, stance leg gluteals, rectus abdominus and both hamstrings[8]. Adductors and iliopsoas have not been included in EMG studies of kicking due to limitations using needle electrodes to access the muscles whilst kicking. From pilot studies the adductor muscles appear to have a similar profile to hamstrings and would presumably show increased activity when kicking across the body[8].

The AFL is the premier and elite competition of the code, which is a Winter league that schedules weekly matches for 16 teams over 22 rounds of a home and away season, plus four rounds of finals[3]. The injury profile for Australian Rules Football is comparable to soccer and rugby union[3].

Methods

A search of the literature (1987-present) was conducted using the following databases: Medline, Ausport, Meditext, Cinahl, Swetswise, Pedro and Science Direct. The following key indexing terms were used: Australian Rules Football Injuries, Australian Rules Football, AFL Injuries, AFL, VFL injuries, VFL. The literature was sorted according to publication date and relevance. Methodological issues and shortcomings of the papers was assessed and conclusions drawn from the results.

Injuries at the Professional Level

In the AFL, there is an average of 37.8 new total injuries per club (of 40 players[3]) each season[2], with an increased incidence of injuries early in the season[9,10]. Overall injury prevalence is consistently higher in the teams based outside Victoria, in Adelaide, Perth, Sydney and Brisbane[11,12]. Players from outside Victoria are slightly (14%) more likely to be injured than players from teams in Victoria, but this isn't statistically significant[11].

The AFL had its second lowest incidence of player injuries last season (2002) than in any of the previous 11 seasons of injury surveillance. The average injury rate for an AFL club for players missing matches per round each year over the past 6 seasons has been 16.0%[2]. The figures for the past 6 years are shown below in Table 1[2]. Each week, 7 players per club miss a match through injury on average[2].

Season	Average injury rate for an AFL club (%)
2002	15.4
2001	15.6
2000	15.1
1999	15.5
1998	16.3
1997	18.3

Table 1: Injury rates for an AFL club for players missing matches per round.

Although injury information is not available for the AFL before 1992, it can be postulated that injuries would have increased over the prior 40 years as the game speed at the top level of Australian football has approximately doubled[13]. Over the same time, the number of collisions and the estimated injury incidence have also doubled[13]. In the period from 1961 to 1997, the proportion of the total game which involves "play" time has been reduced significantly while breaks in play are more frequent and longer. Despite this pattern, the average game tempo has increased along with player height and mass[14]. These are likely determinants of the increased incidence of player injuries as the combination of increased speed and mass implies greater momentum and potential for injury and impact.

Approximately 6.8% of players taking the field each week do so with the assistance of local anaesthetic injections[15], but its use in AFL and professional football codes generally has not been discussed in the medical literature[16,17]. The use of local anaesthetic may risk worsening the injury but professional sportsmen perceive that the risks are often less than the potential benefits of playing the match[16]. This should be fully explained to players and the procedure should only be used when both the doctor and player consider that the benefits outweigh the risks[15]. If the AFL required all occurrences of players being injected with local anaesthetic during a game to be registered as part of doping procedures, then this could also be included within the injury definition[3] and possibly challenge the concept of performance enhancing substances.

Types of Injuries in the AFL

Muscle strains are the commonest injuries in the AFL[18]. The hamstring muscle strain is the highest incident injury[2,3,19,20] over the last 6 years[2]. It is followed by groin strains grouped together with osteitis pubis (due to the high amount of overlap between the two conditions), ankle sprains, quadriceps strains and calf strains[2], all non contact injuries. This is shown below in Table 2. There are slightly more hamstring injuries in the non dominant kicking leg, but this is not significant[7]. The onset of hamstring injuries are evenly distributed throughout the playing season and throughout the quarters of each match[7].

Injury Type	Number of injuries per club per season
Hamstring strain	6.1
Groin strain and osteitis pubis	3.5
Ankle sprains	2.5
Quadriceps strains	2.2
Calf Strains	1.9

Table 2: Highest incidence injuries in the AFL over the last 6 years

The hamstring strain has also accounted for the most time missed due to injury[2,20,21] resulting in 20.8 missed matches per club per season over the last 6 years[2]. This was followed in prevalence by anterior cruciate ligament (ACL) (13.6

missed matches per club per season) and groin strains and osteitis pubis (12.9 missed matches per club per season)[2]. However in season 2002, this trend was reversed with hamstring strains falling to 15.7 missed matches per club, causing less time missed than both knee ACL injuries and groin strains and osteitis pubis, which both increased in incidence from the previous years[2].

In 2002, the incidence of hamstring strains fell to an all time low of 4.5 injuries per club per season[2]. The main reason for a reduction in hamstring injuries is that clubs are more conservative in determining a player's time on the sidelines once the injury has been sustained. The amount of time that players miss per hamstring injury has increased over the last ten years while the recurrence rate has decreased[2], indicating that management has become more conservative and there has been improvements in medical management and coaching or training techniques.

Osteitis pubis injury rates have been on the increase, possibly due to improved diagnosis and heightened awareness, a trend following the greater role of medical media commentators[2]. Athletes with groin pain and tenderness of the pubic symphysis and/or superior pubic ramus have clinical features consistent with the diagnosis of osteitis pubis[22]. This is a slightly more prevalent injury among younger players (causing 11.4 missed games per club per season of players under 24 and 10.7 for players aged 24 or over)[2]. This injury may stand out more because the injury prevalence for younger players is much less than older players[2], but groin pain is associated with increasing age[23]. When kicking, the hip joint of the kicking leg moves through a large range over a short time. As the hip joint of the stance leg is relatively stationary, large joint reaction forces and shearing forces are applied through the pelvis, in particular the pubic symphysis[8]. This may explain why osteitis pubis is commonly seen in AFL players.

In rugby league and union, the most common injuries are head and facial lacerations (11% and 20%) followed by concussion (8% and 5%) (20). The injuries accounting for most time missed are fractures and knee ligament injuries in both rugby codes[20]. In the rugby codes, minor injuries to the head and neck are more common[20]. Although rugby league players suffer the most injuries, AFL injuries are, on average, more severe, and the total time missed through injury by players in these two codes are very similar[20]. Rugby union has a significantly lower injury prevalence at the elite club competition level than rugby league or Australian Rules Football[20]. The most common specific injuries in rugby league are ankle lateral ligament tears, knee medial collateral and anterior cruciate ligament tears, groin musculotendinous tears, hamstring and calf muscle tears, and quadriceps muscle contusions[24].

Injury Recurrence in the AFL

There is a high rate of recurrence for the major injury types, particularly for muscle strains[2], which causes a high overall recurrence rate for all injuries. The recurrence rate for all injuries is 17%[2]. Recurrence was defined as a subsequent injury resulting in a missed match which occurred to the same site later in the season[7]. This is the subject of continuing research[25], with a significant incidence during training sessions[20]. The initial injury was not considered to have fully recovered until the player was selected to play another match. The hamstring strain has the highest rate of recurrence[7]. Recurrence rates over the last 6 seasons are shown below in Table 3[2]. Injuries like fracture, concussion and haematoma have a low recurrence rate[2].

Type of Injury	Recurrence Rate (as a percentage of new injuries)
Hamstring strain	33%
Groin strain and osteitis pubis	22%
Quadriceps strain	20%
Calf strain	18%
Ankle sprain	15%

Table 3: Injury recurrence rates in the AFL over the last 6 seasons

Players returning from a hamstring injury were at a significantly increased risk of re-injuring the hamstring during the first three weeks back from injury (with risk plateauing after four weeks) and more likely early in the match[7]. Leg dominance did not effect the tendency of recurrence[7].

Players who are returning from an ACL injury have a 10 times greater risk of recurrence in the immediate months after their return[2]. They also have a 4 times greater lifetime risk of both re-injury and injury to the opposite leg[2]. AFL footballers with a history of intraarticular ligamentous and/or meniscal injury had a greater risk of functional osteoarthritis and radiological osteoarthritis than those with a history of collateral ligament injury or no injury[26].

Age and Injuries in the AFL

Stress fracture of the foot and lower limb are more prevalent in younger AFL players aged under 24[2]. Hamstring strains, calf strains, lumbar spine and knee cartilage injuries are much more prevalent in older players aged 24 and over[2]. This is shown below in Table 4[2].

Type of Injury	Missed game per club per season (players aged < 24)	Missed game per club per season (players aged 24 +)
Stress fractures of the foot and lower limb	6.6	1.8
Hamstring strain	16.4	28.1
Calf strain	2.0	9.5
Lumbar spine	4.3	10.7
Knee cartilage injuries	4.5	10.8

Table 4: Injury prevalence for players aged <24 and 24+ in the AFL

Injuries at the Amateur Level

Despite the popularity of participation in Australian Rules Football at the community or amateur level, few injury surveillance studies have been published describing the pattern of injuries at this level of participation[27]. There is a lack of good information about injuries to players, particularly of injuries not severe enough to warrant hospital treatment. However, injuries presented to sports medicine clinics for treatment appear to be a good source of data about injuries to non-elite participants[28]. Although, the usefulness of data is limited due to the inability to collect broad exposure data and the biases towards the recordings of injuries only from the more severe end of the injury spectrum[1].

Considering the significant time and cost of what are often relatively minor injuries and the fact amateur Australian Rules Footballers are more likely injured than in other sports[27], more work is required to establish what injuries are most common, and importantly, what measures can be taken to decrease their incidence. In a large 2 year study of injuries at the community level, 40.5% of Australian football participants suffered an injury, followed by hockey (31.0%), netball (19.2%) and basketball (9.3%)[27]. Reliance on injury data from the AFL to guide injury prevention at the community level may not be appropriate due to differences across the levels with respect to exposure, fitness and skill level, along with the longer playing season and shorter off season period at the AFL level[1]. Injury statistics for any professional sport may not necessarily be translatable to community sport level[27].

The injury incidence rates at the amateur level are generally very similar to the AFL[1] or relatively lower[27]. The injury definition used for surveillance over 5 Victorian Amateur Football Association (VAFA) clubs (320 players) over the 1999 season was that of any injury that resulted in missed training time and/or missed competition time and/or required treatment from a health professional[1]. This paper by Gabbe provides the most detailed description of the causes of injuries to community level players. Using this data, there was an average of 1.3 injuries per player over the season with an overall injury rate of 27.2 injuries per 1000 playing and training hours[1]. In another study by Finch, an injury definition was of: an injury occurred whilst participating in sport which led to a reduction in the amount or level of the sport activity and/or the need for advice or treatment and/or adverse economic or social effects[27]. Using this definition there was an injury rate of 20.1 injuries per 1000 playing and training hours[27], although in this study injuries were self reported by the players. Using the AFL injury definition, between 1997 and 2000 there was 25.7 injuries per 1000 playing and training hours[3], but this was only for injuries severe enough to cause a player to miss a match.

The progress of injury prevention research in Australian Rules Football at the community level to date has been slow despite its recognition as a public health goal[29]. In particular, field-based studies to identify injury risk factors and evaluate the effectiveness of injury prevention strategies need to be undertaken to ensure safety gains in this sport.

Types of Injury at the Community Level

Body contact accounts for nearly half of all injuries presenting for treatment at sports physician/medical practitioners[1,28,30] and the most common injuries presenting are medial ligament sprains of the knee, lateral ligament sprains of the ankle and ACL injuries[28,30]. The lower limb is the most commonly injured body region[1,31] accounting for 67.7% of injuries[1], with head and neck second and upper limb third[31]. Of these sites, the thigh is the most commonly injured, in approximately one quarter of cases[1,28], with the hamstring strain being the most common injury, followed by thigh haematoma[1], colloquially known as a "corked thigh" or "corky". The knee, ankle and lower leg are the next most injured areas[1,28]. Muscle and tendon strains are the most common type of injury, followed by joint and ligament sprain and contusions/ haematomas[1,28]. The percentage of all injuries requiring players to seek treatment from a health care professional is 82.3%[28].

Injuries with an overuse component are seen less commonly at amateur than elite level, while traumatic injuries are more frequent[1,31]. Overuse injuries may be correspondingly much less frequent on a time basis alone. The increased incidence of traumatic injuries at the amateur level is postulated to be a manifestation of both less well developed skills and possibly less available and effective preventative measures such as

ankle strapping and tape supplies[31]. Ankle strapping has been demonstrated to reduce injury and re-injury rates[32].

The incidence of injury is greatest in the first four to eight weeks of the season[1,33]. This could reflect poor player preparation, environmental conditions (warmer, drier and harder grounds) or a greater motivation to win earlier in the season[1]. Participants aged between 26 and 30 years have about a 55% greater risk of injury than those aged less than 18 years[33]. A significantly higher proportion of injured players most commonly participate at the senior level compared with the reserve grade (59.6% vs. 40.4% of injuries) and play in the midfield rather than forward or back lines (44.8% vs. 26.1% vs. 29.0% of injuries respectively)[1]. The rate of injury for match participation is over eight times more likely than in training sessions[1].

Football-related deaths identified from the coronial autopsy records of the Victorian Institute of Forensic Medicine (1990-1999) and newspaper reports (1968-1989) recognized 25 deaths associated with Australian football over this period, nine due to brain injury[34]. In all but one case, injury occurred as an accidental part of play. The most common findings in deaths due to brain injury in Australian Rules Football are intracranial haemorrhage, including subarachnoid haemorrhage from vertebral artery injury[34]. More players each year are crippled, paralysed or killed by acute spinal cord injury each year playing rugby union and league than Australian Rules Football[35,36].

Injuries at the Elite Junior level

At the elite Victorian Football League (VFL) under 18 competition, injury prevalence is lesser overall than in the AFL[21]. Injuries that are common in both competitions are hamstring strains, ankle sprains, thigh haematomas, concussion, groin strains and head lacerations[21] with lower limb muscle strains (hamstring, calf, quadriceps) being significantly more prevalent in the AFL than in the VFL under 18 competition[21].

Injuries which are significantly more prevalent in the VFL under 18 competition include stress fractures and concussion[21]. Subsequently, coaches and medical staff have been made aware of the high risk of stress fractures in young footballers with heavy training loads[21]. Players involved in the VFL under 18 competition also play football in other contexts, including for school and local clubs. The median age of players when they first join a VFL under 18 squad is 16.3 years[37]. The players participate in a median of five weekly training sessions during the preseason and play a median of five preseason games[37]. Half of the players participate in 3-4 training sessions per week during the season and one quarter play more than two games per week during the season[37]. Further research is needed to determine whether or not high participation levels have negative impacts on injury risk in these players.

Compounding the injury rate are the beliefs and perceptions of players in the VFL under 18 competition regarding injury risk. These beliefs have the potential to increase injuries and recurrence. In the VFL under 18 competition, 6% of participants believe it is safe to play with injuries and 58% are willing to risk doing so[38]. This increases to almost 80% when players perceived that their chances of being selected to play for a senior elite team in the AFL would be adversely affected if they did not play[38]. These negative and potential harmful beliefs need to be addressed in any comprehensive injury prevention strategy aimed at these players.

Injuries at the Junior Level

Children and adolescents playing community football have the lowest incidence of football injuries at all levels of participation[39]. Vickick (or Auskick), a modified form of the game for children under 8 years, has the lowest rates of injury for all levels of injury severity, with an overall rate of 3.49 injuries per 1000 player-hours[39]. The rate in the under 10 age group is 2.4 times higher than that in Vickick, and the under 15 rate is 1.2 times that of the under 10s[39]. The under 15 age group has significantly more injuries that lead to use of health services than the under 10 and Vickick groups, shown in Table 5. Injuries are largely to soft tissues (sprains 26%, haematoma 25%) and to the lower limb (43%)[39]. Rule modifications in under-10 teams (specifically to the ruck contests at centre or field bounces, decreased contact, field size and player numbers) are associated with an injury rate of 5.8 injuries per 1000 player-hours compared with 7.5 injuries per 1000 player-hours when no modification is used[39]. Body size is not significantly associated with lower injury rates[39]. The percentage of participants in a self reported survey of school age children reported suffering an injury whilst playing Australian Rules Football was 58.4%[40]. However, most injuries in this survey were minor and would not have presented to an emergency or sports clinic for treatment. Using the same survey, comparing injury rates for different sports, there were more injuries playing martial arts (63.9%) and hockey (62.1%) but fewer in netball (51.7%), soccer (47.9%) and basketball (43.1%)[40]. Because this survey was conducted in Adelaide, sports such as rugby union and league were not included and comparisons could not be made between the football codes.

Age Group	Injuries that led to use of health services (per 1000 players-hours)
Under 15	3.93
Under 10	0.64
Under 8 (Vickick or Auskick)	0.33

Table 5: Injury rates at different age groups of junior football

Risk Factors for Injury

Many studies have attempted to identify risk factors to injuries in Australian Rules Football. Further research is needed in this area with the AFL investing more money into this area recently with previous studies having small subject numbers, making conclusions difficult.

Sports medicine dogma advises that low muscle strength, poor flexibility, lack of warm-up, failure to stretch, and muscle fatigue are risk factors for muscle strains, and that these injuries can therefore be prevented. The scientific evidence to support these beliefs is lacking[18]. Hamstring and spinal flexibility in Australian Rules Footballers (as measured by the sit-and-reach test and the toe touch test) does not correlate with injury[18,41].

Hamstring, quadriceps, and calf muscle strain injuries at the AFL level have been associated with significant risk factors. For all injuries, the strongest risk factor is a recent history of that same injury and the next strongest risk factor is a past history of the same injury[18,42]. Age is a risk factor for hamstring[7,18] and calf muscle strains (even when adjusted for injury history) but is not a risk factor for quadriceps muscle strains[18]. Quadriceps muscle injuries are significantly more common in the dominant kicking leg, whereas hamstring and calf muscle injuries show no difference in frequency between the dominant and non-dominant legs[18].

History of one type of muscle strain increases the risk for certain types of other muscle strains. Hamstring strains are more common with past calf injury[18]. Calf muscle injury is associated with past quadriceps injury[18]. Quadriceps muscle injury is associated with a past history of hamstring injury[18]. Quadriceps injuries are also more common in shorter players and when there had been less rainfall at the match venue in the previous week[18]. It is likely that during a kick, the quadriceps muscle tears at the time of ball contact, when the ball transmits a retarding torque and eccentric movement on the extending thigh[8]. There is a potential for this injury rate to be decreased by changing the mechanics of the ball, such as lowering the pressure of inflation, which may increase contact time and decrease peak retarding force[8]. Current ball pressure is set at 69Kpa, but can vary between 62 and 76kPa[6].

However, the other major muscle group that is commonly injured in AFL players, the adductor group (groin area), has not been included in analysis because the diagnosis and onset of injury are often not specific[18].

The only reversible risk factor for hamstring muscle injuries for which there is any good degree of clinical evidence is low strength[18]. In a study involving 2255 matches of AFL between 1992 and 1999, the injured hamstring muscles were all weaker than in the opposite leg in absolute values and hamstring-to-quadriceps muscle ratios[19]. Hamstring muscle injury was significantly associated with a low hamstring-to-quadriceps strength on the injured side and a low hamstring muscle side-to-side ratio[19]. These results indicate that preseason isokinetic testing of professional Australian rules footballers can identify players at risk of developing hamstring muscle strains. However, one more recent and larger study contradicts this, saying there are no significant differences for any of the isokinetic variables comparing the injured and non-injured legs in players with unilateral hamstring strains[42].

Another risk factor for hamstring muscle strain at the AFL level found using magnetic resonance imaging (MRI) to define the diagnosis (specifically intramuscular hyperintensity on T2 weighted MRI) exists between injury and each of the following: increasing age, being of Australian Aboriginal culture, past history of an injury to the posterior thigh or knee or osteitis pubis[43]. These factors are still significant when players with a past history of posterior thigh injury are excluded[43]. Previous back injury is associated with posterior thigh injuries that look normal on MRI scan, but not with an MRI detected hamstring injury[43].

Other factors that may explain the high incidence of hamstring and groin injuries in Australian Rules Football compared to other sports include: greater distance of sprinting during average effort, the less predictable flight of the ball, large length of the playing field, the fact that players kick the ball more, repetitive loads in kicking and long duration of games[8].

Less is known about the risk factors for strains of muscle groups other than the hamstring muscles.

Between 1992 and 1999 in the AFL the strongest risk factors for an ACL injury were a player history of anterior cruciate ligament reconstruction either in the previous 12 months or before the previous 12[26]. The increased risk of injury in the first 12 months after reconstruction was associated with the reconstructed knee, whereas after 12 months there was an even distribution of new injuries to the reconstructed knee and contralateral knee[26].

The prevalence of mouthguard use during matches varies between 60% for juniors and 90% for elite footballers whereas the mouthguard use during training ranged between 2% for junior and 40% for elite players[44]. Wearing mouthguards while playing contact sports reduces the prevalence and severity of orofacial injuries[45]. When a mouthguard was not worn, the likelihood of a fractured or avulsed tooth was at least twice that when a mouthguard was worn in amateur footballers[45]. A finding noted in other sports[46,47].

Ground Hardness and Surface Characteristics

Ground hardness has been measured using a penetrometer at AFL games since 1997 in response to the finding that the overall injury prevalence was consistently higher in the teams based outside Victoria (harder grounds) compared to teams based in Victoria (softer grounds)[11,12]. Many of the lower limb injury categories had greater incidence in players outside Victoria, including ankle injuries, ACL injuries, groin and hip injuries, calf strains and quadriceps strains[11]. The majority of these injuries had a non-contact mechanism. Lower limb stress fractures did not show a significant difference between groups, although these injuries were infrequent (11). There is a non-significant trend towards a higher risk of ACL injury with harder grounds (10). The only injury categories showing a statistically significant relationship between hardness and injury risk are acromioclavicular joint sprains (more likely on harder grounds) due to impact on the ground and facial fractures (more likely on softer grounds)[2] which is hard to explain. There is also a significant relationship between ground hardness and game speed, which could lead to higher injury rates when the ground is harder[13]. Factors other than ground hardness that are certainly involved with the relationship between ground conditions and injury, including grass type, grass density, player boot selection, water evaporation and rainfall[9-12] and speed of the game[13,14].

The most reasonable explanation for high rates of injury to the lower limb and an increased incidence of injuries early in the season involves variations in playing surface characteristics[9]. Shoe-surface traction for the average player is the specific relevant variable that is most likely to correlate with injury incidence in a given game of football[9]. Shoe-surface traction will usually have a positive correlation with ground hardness, dryness, grass cover and root density, length of cleats on player boots and relative speed of the game[9]. But to date, the relative contributions of ground hardness, grass type, shoe-surface traction and other confounding factors have not been determined[10]. It is possible that measures to reduce shoe-surface traction, such as, ground watering and softening, play during the winter months, use of natural grasses such as perennial ryegrass and player use of boots with shorter cleats, would all reduce the risk of football injuries[9]. The most pronounced protective effect is likely to be on injuries to the lower limb of a non-contact nature, including ACL injuries.

There is a non-significant trend towards an increased risk of ACL injury in games where the predominant grass type was couch (Bermuda) grass, as opposed to rye grass[10]. Because of the apparent connection between increased traction and injury risk and the likelihood that couch grass grounds lead to higher traction than rye grass, all AFL grounds over the last few years have moved to make rye grass their most predominant type.

High water evaporation in the month before the match and low rainfall in the year before the match are significantly associated with ACL injuries[12,26]. Low water evaporation and high rainfall significantly lower the risk of ACL injuries in AFL footballers[48]. The likely mechanism is a softening of the ground, which lowers shoe-surface traction. Consistent extra watering and covering of grounds during periods of high water evaporation may lower the rate of ACL injuries[12]. It is likely that ground cover and traction play a more important role than ground hardness with risk of ACL injury[9].

Conclusion

Injuries in Australian Rules Football are most likely non contact and soft tissue in nature, occurring to the lower limb. The hamstring strain is the most common injury and on average, accounts for the most time missed from play and has the highest risk of injury recurrence. Incidence of injury increases with higher levels of play. Further research is required to explain aetiology and risk factors for injury as well as treatment and management efforts.

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