Concussion incidence and time-loss in Australian football: A systematic review

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Abstract

Objective Australian football is associated with a risk of concussion. However, despite the extensive and varied nature of literature devoted to this issue, concussion incidence has not been systematically evaluated. To address this, we aimed to conduct a meta-analysis of concussion incidence in Australian football.

Design Systematic review. Prospero registration number: CRD42017064290.

Method A systematic search of 14 databases using the terms 'concussion', and 'Australian football' (and variations) was used to obtain records that reported concussion incidence per 1000 players hours across age, sex, and level-of-play. Data were grouped based on how time-loss was applied to the concussion definition.

Results Forty-two studies met inclusion criteria. Incidence rates based on a possible time-loss definition per 1000 player hours, ranged from 2.24 to 17.63 at the elite level, and 0.35 to 14.77 at the community/amateur level. Return-to-play details were reported by six studies and only two studies measured head-impacts in real-time. Several limitations were identified with this literature. First, insufficient return-to-play details precluded a meta-analysis of incidence rates. Second, no longitudinal studies across levels-of-play were found. Third, concussion incidence data for junior and female players were notably scarce.

Conclusion There was limited scope to determine concussion burden (i.e., incidence and severity) and only preliminary data for player exposure to head-impacts. To address these limitations, injury surveillance should capture sufficient information to permit comparisons within and across levels-of-play. This will also help determine the influence of interventions aimed at reducing the frequency and severity of concussive-injuries.

Keywords Brain injury; Australian Rules Football; Epidemiology; Time-loss; Return-to-play

1. Introduction

Australia's sporting landscape is dominated by Australian football (AF), a fast-paced contact sport that involves frequent collisions through tackling and contested possessions.[1,2] A formal competition, the Victorian Football League (VFL), was established in 1896 and became the Australian Football league (AFL) in 1990. AF is one of the most popular sports in Australia, with 18 elite teams in the AF, the introduction of the AFL for Women (ALFW) in 2017, and 1,547,915 community-level participants.[3] As a contact sport AF invariably carries a risk of injury.[4-19] Yet despite rules designed to protect a players' head (e.g., no hip and shoulder action resulting in head-impact),[2] concussive injuries[4-20] and head-impacts[21] continue to occur, and are the focus of this review.

Concussion in sport, including AF, is classified as a traumatic brain injury (TBI) induced by biomechanical forces.[22] Its multifaceted nature is highlighted by the definition produced following the 5th International Conference on Concussion in Sport, paraphrased as: (1) head, neck, or face-contact; (2) rapid onset of short-term neurological impairment followed by spontaneous resolution or persistence up to hours; (3) potential neuropathological changes, with acute clinical manifestations likely indicating a functional rather than structural injury; and (4) including a range of clinical signs and symptoms, with or without loss of consciousness, followed by a sequential course of resolution or possible prolonged course.[22] In addition, a recent review highlighted that structural changes following concussion may only be identified with advanced neuroimaging approaches capable of detecting subtle anomalies.[23] This reinforces that our understanding of the potential effects of concussion, particularly at a cortical level, continues to evolve and requires ongoing exploration.

Recommended sports-related concussion management involves screening a player suspected of sustaining a concussion, immediately removing them from play, and following concussion diagnosis, conducting assessments with resumption of play dependent on individual recovery trajectories.[22] Time-loss (e.g., a minimum 24 hours of restricted participation[24] or a missed game[14]) is linked to recovery from concussion and has been considered a marker of concussion severity.[25] For example, return-to-play (RTP) protocols include symptom assessments, and persistent symptoms (i.e., greater than 10 to 14 days in adults and over 4 weeks in children[22]) suggest a delayed recovery that likely involves time-loss. However, limitations need to be considered when applying time-loss as a marker

of severity. First, not all players who sustain a concussion will be screened during the game/training in which the concussion occurred, particularly if symptoms only emerge later, [22] thereby potentially reducing the accuracy of the time-loss duration recorded. Second, if only time-loss concussions are tracked, concussions that did not result in greater than 24 hours of restricted participation (typically considered a *non-time-loss* injury[24]) or in a missed training session or game, will not be recorded, leading to under-reporting of concussion incidence. Third, players may RTP despite being symptomatic,[22] rendering the relationship between severity and time-loss largely meaningless. Fourth, players are required to be asymptomatic for a greater duration before resuming play compared to previous years,[26] which may foster the possible inaccurate assumption that concussions are becoming increasingly severe because of increased time-loss durations. Finally, the implementation and enforcement of screening and management protocols following self-reported or observed head-impact, depends on the resources and priorities of individual clubs and on player behaviour.[27] Collectively, these sources of variance potentially bias any incidence and time-loss details recorded.

However, despite the limitations with employing a time-loss approach, surveillance protocols often include time-loss in terms of a missed game as a core criterion to determine concussion/injury incidence.[4-17,28] This occurs even though the *diagnosis* of a concussion does not mandate any time-loss. For example, from 1992 the AFL introduced mandatory reporting of injuries, and in 1996 commenced annual AFL Injury Reports (AFL-IRs); from 1997 onwards, the AFL have defined an injury, including concussions, as an '*injury or medical condition which causes a player to miss a match'*.[4-17] This is despite an assessment by the AFL on the effect of rule changes on AFL injuries highlighting how the time-loss injury definition is *'... less appropriate'* for monitoring concussions, as it under-reports concussion incidence.[29] Consequently, although time-loss details can contribute to our understanding of the impact of a concussive injury, this is only possible if: 1) a player is appropriately managed (i.e., symptomatic presentations are treated in accordance with time-loss protocols); and 2) all time-loss details, including any periods of non-participation that do not necessarily result in a missed game, are recorded.

By extension, when considering the risk-profile for concussion, facilitating direct comparisons both within and between different levels-of-play and across sports, requires that incidence data be

reported in a comparable format. Presenting data per 1000 player hours accommodates match duration and is considered an accurate measure of concussion/injury incidence.[25,28,30] In addition, assessment of injury recovery via time-loss (i.e., time-to-RTP), coupled with incidence per 1000 player hours, reveals *injury burden* in terms of lost time per 1000 player hours. This is a useful metric when considering the risk-profile of specific injuries both within and across sports and is in-line with healthcare research that considers the burden of disease by combining incidence rates and time lost.[25] However, as there is no consensus on guidelines for reporting injuries –including concussion– injury surveillance approaches typically fail to report both the incidence in a comparable format and time-loss specifics.[25] These limitations independently and collectively undermine the accuracy of concussion tracking approaches and may lead to under-reporting of concussion burden. Care should be taken not to discount those injuries that resolve without time-loss or with less than 24 hours of time-loss, and to avoid concluding that an absence of time-loss indicates an injury of reduced severity.

As demonstrated, sustaining a concussion clearly does not require that time-loss occur, however, whether a concussion is included in incidence rates often, but not always, depends on this criterion. It therefore forms a critical component of data collection practices that needs to be considered when analysing results and to permit accurate comparisons of trends. For the purpose of this review, injury/concussion definitions are categorised as follows: 1) a *time-loss* definition mandated that a player miss a game or training session; and 2) a *possible time-loss* definition either did not mention time-loss, or specified that *time-loss,* in terms of a missed game/training, or interference with any degree of participation, was a sufficient –but not mandated– criterion. The *possible time-loss* definition also incorporates *non-time-loss*; this accommodates time-loss that may include only game-day time-loss or time-loss of less than 24 hours.

The recently updated position statement on concussion in sport in Australia, collaboratively produced by the Australian Institute of Sport, Australian Medical Association, Australasian College of Sport and Exercise Physicians, and Sports Medicine Australia,[31] reflects the scope and complexity of concussive injuries. Specific to sport-related concussion incidence it was noted that data in Australia is limited, with difficulties in data collection including symptom recognition, and athletes under-reporting and failing to consult medical professionals.[31] Inadequate knowledge of concussion

incidence and time-loss suggests methods of concussion surveillance need to be addressed. Yet while sports-related concussive injuries are a growing public health concern in Australia[31] and internationally,[32] a systematic review of concussion incidence and time-loss literature in AF has not been conducted. Furthermore, it is unclear how rates compare across levels-of-play and with other sports. This is particularly important for concussion management and prevention as failing to capture sufficient data will prevent us from drawing accurate conclusions about the effectiveness of protocols designed to decrease the rate and severity of concussions in AF.

Therefore, this is a timely systematic review that primarily aimed to determine the incidence of concussion and time-loss specifics in AF and compare results across levels-of-play. A secondary aim was to explore head-impact exposure rates (e.g., sub-concussive impacts) in AF. Findings are discussed with regard to methodological approaches designed to track concussion incidence, particularly the limitations identified with the incidence inclusion criteria applied, and recommendations are made for future concussion surveillance practices in AF.

2. Methods

A protocol that incorporated concussion incidence was registered with PROSPERO (registration number: CRD42017064290) and PRISMA guidelines were followed. Studies with participants who were concussed or exposed to head-impacts, including sub-concussive impacts, while playing AF were identified via an electronic search of 14 databases on April 8, 2018, using variations of the terms 'concussion' AND 'Australian football' (see Supplementary Table 1 for the databases and PubMed search strategy). Although not always peer-reviewed, AFL-IRs provide elite-level concussion data and were sourced using Google. Author CM performed all searches.

Articles were included if they: (a) were peer reviewed (unless an AFL-IR), English language journal articles, published or in press, up to April 8, 2018; and (b) reported head-impact (including sub-concussive) exposure rate, or concussion incidence per 1000 player/game/training hours (or provided data to enable conversion), in participants who played AF, regardless of age, sex, or level-of-play. Following removal of duplicates, author CM screened records on title and abstract to determine full-text articles for review (see Supplementary Figure 1 for the PRISMA flowchart).

Authors GC and CD independently screened 20% on title and abstract to ensure consistency with the full-text articles selected. CM and GC independently screened the selected 264 full-text articles to determine the final selection of 42 articles.[4-21,33-56]

The following data were extracted by authors CM and GC: 1) study aim; 2) level-of-play; 3) participant characteristics; 4) concussion definition and diagnosis; 5) concussion incidence rate (or conversion data); 6) return-to-play/time-loss details; 7) mechanisms of injury; 8) concussion injury ranking; and, where applicable, 9) head-impact exposure rate. Terminology used within each article was maintained for data extraction. Authors CM and GC independently assessed risk-of-bias using a 10-item questionnaire previously used to assess sports injury data.[57]

As this review focused on concussion incidence per 1000 player hours, the following equations were applied in-line with previous meta-analyses:[28,30]

$$Concussion\ incidence = \left(\frac{Number\ of\ concussions}{Number\ of\ matches \times Number\ of\ players \times Match\ duration[hours]}\right) \times 1000$$

OR

$$Concussion\ incidence = \left(\frac{Number\ of\ concussions}{Player\ hours}\right) \times 1000$$

Despite data in a standardised format, individual findings could not be combined as time-loss details were not provided; this rendered the data too heterogenous. For example, studies that used a *possible time-loss* definition potentially combined concussions that did and did not result in time-loss into one incidence rate. That is, even where a definition does not mandate time-loss, it does not negate that time-loss may have occurred. Indeed, nine studies that did not mention any time-loss details in the definition, noted within the findings that games or training at the concussive injury level[20,40,49,51,53-55] or injury-category level[35,37] were either missed or may have been missed. As such, the criteria used to quantify concussions across the included studies have nuances that are unaccounted for and

prevented meaningful comparisons from being made with a meta-analytic approach; a narrative synthesis was therefore conducted.

3. Results

The final selection of 42 articles included 16 AFL-IRs;[4-19] 18 articles on injury surveillance;[33-50] six empirical articles that reported concussion incidence,[20,51-55] and two that reported head-impact exposure. [21,56] All players participated in AF in Australia. From a total possible score of 10, where 10 indicates a low risk-of-bias, the overall risk-of-bias average (excluding head-impact exposure studies) was 7.7. See Supplementary Table 2 for individual study scores. As only two studies explored real-time head-impact kinematics, results are presented in Supplementary Table 7.

The protocol for concussion diagnosis included diagnosis or verification by club medical staff,[20,33-36,38-40,50-55] with data entry performed by a club doctor,[38,39,41] sports trainer[37,41,46,] physiotherapist,[41,48] player self-report,[42] or by a nominated team parent/teacher/coach/manager/staff member/trained volunteer[37,43-47,50] Mechanism of injury details were predominantly reported at the total[47,35,37,41,43,45] or broad injury-category level,[46,50] rather than the specific concussive-injury level.[53,54]

Focusing on non-AFL-IRs, Table 1 outlines incidence rates per 1000 player hours, confidence intervals, and time-loss details reported in concussion definitions, by level-of-play. All studies included only male participants; one junior-level study included 17 female participants,[37] however injuries were reported at the total rather than sex-specific level. A time-loss definition was used by only one study.[50] With the exception of amateur-level data collected in 1993,[39] rates at the elite-level were consistently greater than at the community/amateur-level. However, there were no other consistent trends based on level-of-play or definition (see Supplementary Table 3 for additional data).

189 **Table 1** Concussion incidence rate per 1000 hours and time-loss details

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Time-loss					
Lathlean et al. [50]	Junior-elite 2014	562 32,043.01[d] MT	1192 6	0.19[a] (0.08-0.39)	Player must have missed a full training session or game.
Possible time-loss					
Sali et al. [34]	VFL 1979	449 11,040	531 30	2.72[b] (1.87-3.83)	Includes possible time-loss from exclusion from game-play, interference in training, or a missed game.
Shawdon et al. [39]	Amateur: adult 1993	80 541.67[d]	52 8	14.77[a] (6.86-28.05)	Includes possible time-loss from a missed game.

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Dicker et al. [36]	VFL 1979, 1980, 1982	1287 29,568[d]	1408 74	2.50[b] (1.98-3.12)	Includes possible time-loss from interference with subsequent play and training.
Seward et al. [38]	AFL 1992	NR 15,177[d]	All injuries: 941 34	2.24[a] (1.58-3.10)	Includes possible time-loss from a missed game or training.
Finch et al. [42]	Community: junior/adult 1997-1998	547 36,218.91[d] MT	AF specific: 728 AF specific: 48	0.50[a] (0.30-0.77)	Includes possible time-loss from reduction in the amount or level of participation.
Gabbe et al. [41]	Amateur: adult 1999	320 12,867.64[d] MT	350 11	0.85[a] (0.45-1.49)	Includes possible time-loss from missed game-time or training session(s).

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Grimmer et al. [43]	Community: junior 2000	Total: 697; UD U13: 87; 4629.63[d] U15: 183; 7034.48[d]	Total: 234; 6 U13: 50; 2 U15: 102; 4	Total: UD U13: 0.43[a] (0.07-1.43) U15: 0.57[a] (0.18-1.37)	Includes possible time-loss from significant interference with enjoyment of sport.
Braham et al. [44]	Community: adult 2001	294 14,230.77[d]	HNO: 37 7	0.49[a,c] (0.22-0.97) (based on HNO injury incidence)	Time-loss not mentioned.
Braham et al. [45]	Community: adult 2001	301 17,355.37[d] MT	210 9	0.52[a,c] (0.25-0.95) (based on overall injury incidence)	Includes possible time-loss from an incomplete or missed training, session, or game.
Twomey et al. [47]	Community: ≥ 18 2007-2008	NR 8979.59[d]	352 14	1.56[a] (0.89-2.55)	Includes possible time-loss from missed game-time. Time-loss injury severity noted.

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Colby et al. [48]	AFL/WAFL 2012	Total: 46; 30,459 MT Pre-season: NR; 1405.8 MT In-season: NR; 1700.4 MT	297; 13 110; 4 187; 9	4.19 (2.33-6.98) 2.85 (0.90-6.86) 5.29 (2.58-9.71)	Includes possible time-loss from modified participation, or a missed game(s) or training(s). Time-loss injury severity noted.
Ferguson et al. [33]	NR (published in 1965, with injuries from 'over 18 years')	~2600 (reported as an estimate) 13,000	792 21	1.62 (1.03-2.43)	Time-loss not mentioned.
Hoy et al. [35]	Community: seniors 1981	449 2752	531 30	3.11[c] (1.45-5.91)	Time-loss not mentioned.

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Orchard et al. [40]	AFL 1994-1997	86 5895.27[c]	2308 70	11.87[a] (9.33-14.91)	Time-loss not mentioned[e]
McMahon et al [37]	Community: children and adolescents 1992	Total: 1253; 30,459 Under 15: 565; 15,024	246; 15 147; 12	0.49[a] (0.29-0.79) 0.80[a] (3.47-12.51)	Includes possible time-loss from interference with normal functioning during training, game, school, or leisure.
McCrory et al. [51]	AFL 20-week season	303 6969.70[d]	NA 23	3.30 (2.14-4.87)	Time-loss not mentioned[e]
McCrory et al. [52]	AFL 1995-1997	303 7187.50[d]	NA 23[f]	3.20 (2.08-4.73)	Time-loss not mentioned.

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Makdissi et al. [53]	AFL 2000-2003	158 24,642.86[d]	NA 199 (138 cases analysed)	5.60 (4.72-6.60)	Time-loss not mentioned[e]
Makdissi et al. [20]	Elite, elite-junior, community 2001-2004	Elite: 675; 20,571.43[d] Elite-junior: 272; 4615.38[d] Community: 68; 3125[d]	NA; 72 NA: 6 NA; 10	3.50 (2.76-4.38) 1.30 (0.53-2.70) 3.20 (1.63-5.70)	Time-loss not mentioned[e]
Romiti et al. [46]	Community: junior 2004	NR 39,722.22[d] MT	715 14	0.35[a] (0.20-0.58)	Time-loss not mentioned.
Fortington et al. [54]	Community: adults 2007 or 2008	1564 68,094.24[d] MT	143 34	0.50 (0.35-0.70)	Includes possible time-loss from missed game-play[e]

Reference	Level-of-play Season(s)	Players, n Player hours, n	Injuries, n Concussions, n	Concussion incidence per 1000 hours (95% CI)	Time-loss details provided in the definition
Makdissi et al. [55]	AFL 2011	764 9425.29[d]	NA 82[f]	8.70 (6.96-10.74)	Includes possible time-loss from missed game-play.
Gibbs et al. [49]	AFL 2000-2013	Total: 116; 7972.02 Regular: 226; 7373.52 Finals: 116; 598.5	NA; 140 NA; 130 NA; 10	17.56 (14.83-20.66) 17.63 (14.79-20.86) 16.71 (8.49-29.78)	Time-loss not mentioned[e]

Note. All Confidence Intervals were estimated using the exact Mid-P method.[58] Article-specific terms are reported (e.g., match or player, community or amateur). ≥ **:** Greater than or equal to. **HNO:** Head/neck/orofacial. **HNF:** Head/neck/face. **NA:** Not applicable (applies to studies that only focused on concussive injuries). **MT:** Match and training hours. **NR:** Not reported. UD: Unable to determine. **WAFL:** Western Australian Football League. [a]Incidence calculated (see Supplementary Table 3). [b]Incidence calculated using person-risk hours. [c]Data from the same sample. [d]Player hours calculated. [e]Time-loss or possible time-loss noted in results. [f]Concussions reported from video analysis retrieved from the AFL Medical Officers (AFLMO) Injury Survey Database.

Several reporting formats were used in the AFL-IRs. The majority reported a time-loss injury definition;[4-17] two did not include any definition[18,19] but presumably used a time-loss definition, while new concussions per club per season and concussion prevalence (i.e., missed games per club per season) were consistently recorded.[4-19] In the 2016 AFL-IR,[19] concussion incidence from 2011 to 2016 was reported as the number of concussions per 1000 player hours of exposure, regardless of matches missed. From 1992 to 2016, time-loss concussion incidence per 1000 player hours of match exposure were calculated using conversion details provided in the 2012 AFL-IR[15] (see Supplementary Tables 4, 5, and 6 for AFL concussion data).

As detailed in Table 2, the difficulties in comparing incidence rates as a function of the time-loss definition applied are demonstrated by data from the AFL-IRs and individual studies that assessed elite players during the same season(s). For example, a 14-year surveillance of one AFL club that did not require time-loss for a concussion to be included, generated an incidence rate of 17.63.[49] As no concussion resulted in a missed match[49] applying a missed match time-loss definition would have produced an incidence rate of zero. The comparable time-loss incidence rate from the AFL-IRs was 0.59.[4-16] As shown, possible time-loss figures were between 5.33 to 41.97 times higher than time-loss incidence across all adult elite-level comparisons.

Table 2 Incidence rate comparisons based on time-loss at the elite and junior-elite levels

Level-of-play Season(s)[a]	**Average concussion incidence: new concussions per club per season** (time-loss)[b]	**Concussion incidence: per 1000 player hours of match exposure** (time-loss)	**Average concussion incidence: per club per season** (possible-time-loss)	**Average concussion incidence: per 1000 player hours** (possible time-loss)
Elite				
1992	1.3 [4]	1.08[c]	-	2.24 [38][d]
1994-1997	0.80 [4]	0.67[c]	-	11.87 [40][d]
1995-1997	0.80 [4]	0.67[c]	-	3.2 [52]
2000-2003	0.58 [4-6]	0.48[c]	-	5.6 [53]
2000-2013	0.59 [4-16]	0.49[c]	-	17.63 [49]
2001-2004	0.5 [4-7]	0.42[c]	-	3.5 [20]
2011	1.1 [14]	0.92[c]	7.7 [19]	8.0 [19]
2012	1.0 [15]	0.83[c]	9.1 [19]	9.4 [19]; 4.19 [48]
Elite-junior				
2001-2003	-	-	-	1.3 [20]
2014	-	0.19[50]		-

Note. – No data. [a]AFL club averages for injury statistics are scaled to 40 players over 22 matches. [b]Incidence calculated using data from AFL-IRs. [c]Incidence calculated using 'approximate' player hours and conversion details provided in the AFL-IR for season 2012 [15]: $(\frac{concussion\ incidence}{1200}) \times 1000$. [d]Incidence calculated (see Supplementary Table 3).

When considering the injury-risk profile of a sport, injury burden can be demonstrated by creating a risk matrix that considers the relationship between severity (i.e., number of days lost) and incidence (i.e., per 1000 player hours).[25] In the current review, RTP details at the concussive-injury level were

only reported by six[20,40,49,51,53,54] of the 42 studies. One study noted that while 88% of players left the field immediately post-concussion, 47% RTP that game,[54] with further time-loss details reported according to the injury-category of 'head injuries', not concussion. A median 4.8 days were lost to concussion across elite, junior-elite, and community-level competitions, and while no significant differences in average RTP time-frames across levels were reported,[20] level-specific RTP details were not provided. Only four studies reported days or matches lost at the group-[40] or player-level[49,51,53] Specifically, 16 competition matches were missed from 70 concussions at the elite-level,[40] while among 23 elite-level players who sustained a concussion, 10 returned the day-of-injury, 6 returned by day-7, and 7 returned by day-14.[51] A video analysis of 138 elite-level concussions noted that 11 resulted in one missed game.[53] In contrast, another study at the elite-level found that from 140 concussions, no games were missed.[49] Given the either absent or incomplete reporting of time-loss details across the majority of studies, a meaningful interpretation of concussion burden in the AF, incorporating both incidence and severity, was not possible.

4. Discussion

This article presents a comprehensive review of concussion incidence, time-loss, and head-impact exposure involving Australian footballers. Failing to report time-loss details and variations in the concussion/injury definition applied, made it particularly challenging to compare incidence and rendered a meta-analytic approach unsuitable. Similar to findings in Rugby Union,[28] incidence rates per 1000 player hours differed across and within levels-of-play. A possible time-loss definition produced incidence from 0.35[46] to 0.80[37] at the junior community-level; from 0.49[45] to 14.77[39] at the adult community-level; and from 2.24[38] to 17.63[49] at the elite-level. In addition, only seven studies[41,42,44-46,48,50,54] reported a combined training and match incidence rate, and only two[44,54] reported the number of concussions sustained during training (i.e., no concussions occurred). While this may indicate that concussions occur infrequently in AF training sessions, explicit reporting of the concussion location and training hours are required to accurately determine incidence and concussion risk. It is clear, however, that incidence rates were a direct function of how the time-loss criterion were applied. Thus, in order to permit generalisations of concussion trends specific to each level-of-play and promote more

meaningful interpretations of the data generated (e.g., promote targeted concussion prevention), studies and surveillance reports should aim to record *all* concussions, alongside mechanism of injury and RTP time-frames.

At the elite-level, considerable differences were found between time-loss and possible-time-loss incidence rates across the same season(s). For example, when applying a time-loss definition for concussion incidence per 1000 player hours of match exposure in the AFL, the rate was 0.92 for the 2011 season. In contrast, using a possible-time-loss definition with the same metric generated a rate of 8.70.[55] Similarly, across the 1994 to 1997 seasons, the time-loss incidence rate was 0.67, but the possible-time-loss rate was 11.87.[40] In both instances, the *definition* applied for the higher incidences did not mention time-loss, yet one study noted incidence was recorded *'...regardless of matches missed'*,[55] and the other reported 16 competition matches were missed due to concussion[40]. This indicates that the majority of concussions did not result in a missed match. The lack of missed matches is potentially due to the time between AFL matches, which is typically from 7 to 9 days. It is also possible that players were RTP despite being symptomatic, which highlights the possible failure to adhere to mandated head-impact protocols. This was demonstrated by a recent review focused on European football (soccer) that revealed during the 2016 Union of European Football Association Football Championship, 72.4% of elite male soccer players suspected of sustaining a concussion were not medically assessed in accordance with international recommendations.[59]

A change in incidence rate can only be interpreted as meaningful if the baseline data is complete. Therefore, failing to effectively manage head-impacts and record details about each concussion across levels-of-play will render assessment of concussion interventions largely incomplete from a clinical perspective. Complete recording in the first instance, coupled with complete reporting of concussion incidence in the public domain, will ensure that the decision process around whether to participate/continuing participating, incorporates an accurate understanding of concussion risk. The inclusion of concussion incidence rates (but not any other injury rates) reported per 1000 player hours, regardless of any matches missed, in the 2016 AFL Injury Report,[19] reflects an attempt to address the issues present when using only a time-loss definition for concussions. In-line with surveillance reporting in other sports,[24] a more accurate approach for AF would be to record how long players are

289 restricted for, with regard to participating in sports-related activities. This will help reveal player-
290 specific RTP trajectories that better depict the concussion landscape in AF.

291 Large samples over more than one season at the elite-level are anticipated, as AFL player contracts
292 include consent for the use of player injury data for research purposes.[13-17] However, while comparable
293 sample sizes were found at the community/amateur level,[37,42,43,54] incidence rates at this level were
294 typically lower than at the elite-level. This could reflect the limited ability to capture complete data. For
295 example, a recent survey revealed that AF coaches and sports trainers at the community-level
296 experienced difficulty implementing concussion guidelines due to issues such as parents and players
297 disputing or resisting the decisions made.[27] The differences could also reflect the services available;
298 while players at the elite-level have access to medical personnel to diagnose a concussion and video
299 review to ensure head-impact incidents are followed-up, at the community-level, the onus is often on
300 the player to self-report a head-impact before concussion protocols are implemented. However, despite
301 these advantages at the elite level, it is important to note that head-impacts may go unreported. This
302 was demonstrated in American Football, where the likelihood of reporting a concussion to a medical
303 professional was only 47%, compared to 80% for other injuries.[60] This further highlights that
304 concussions are systematically under-reported across sports.

305 The possible limited capacity to identify all concussions also potentially explains why only two
306 studies[54,55] (one of which included video analysis at the elite-level[55]) reported mechanisms of
307 concussive-injury. Insufficient reporting of mechanisms of injury were similarly reported in a review
308 that considered injury prevention in community AF.[61] Finch and colleagues found that a combined
309 mechanism of injury for all injuries was predominantly reported, as opposed to providing details for
310 specific injury categories or body regions.[61] Tracking incident-specifics will help identify trends and
311 potentially promote level-specific injury prevention approaches that improve player safety (e.g., by
312 isolating modifiable factors that contribute to head-impacts).

313 Two player groups, female and junior athletes, were inadequately represented in the literature. While
314 the lack of data involving female AF players is striking, it is consistent with research involving female
315 athletes in contact sports.[62] Despite only recent advancements in terms of professionalism of women's
316 AF, women have competed in formal competitions nation-wide for decades, with the earliest recorded

league established in 1992. In 2017, 463,364 females participated in AF, alongside a 76% increase in the number of female teams in Australia.[3] Yet female AF players were only included in one study that focused on injury incidence[37] and one focused on head-impact exposure.[21] In addition, the majority of studies referred to a specific league or level-of-play without mentioning gender;[33-36,38-40,43-52] the inference being that a study on AF could only include males. Given the number of female footballers is likely to increase as the AFLW expands, a concerted effort must be made to track these female athletes to ensure appropriate concussion protocols are implemented and long-term consequences are managed, or indeed prevented. This is particularly important given a recent review revealed that females competing in soccer and ice-hockey were at a greater risk of concussion compared to male players.[62]

The lack of data involving younger players is also notable. However, while data for young players can be captured through participation in Auskick, which is AF for children that applies modified rules which change as children age,[63] evidence highlights that recording injury information, particularly at the community-level, is challenging. Findings from a recent survey revealed parents of community-level junior AF players often have difficulty determining when a child has sustained a concussion.[64] In addition, the evaluation of an implemented injury surveillance system found that of the 78 AF clubs involved, only 9% implemented the system for a second season, with the majority (69%) not progressing beyond being advised about, or trained in, how to use the system.[65] While the studies in the current review used various reporting methods, concussions at the community-level were often recorded by club volunteers. This suggests that ongoing attempts to improve surveillance will require an adaptable reporting approach developed in consultation with players and club/team stakeholders. In addition, given the community setting of Auskick, which had 200, 138 participants in 2017[3], hospital-based data is more likely to capture children injured at this level. However, relying on this approach will likely fail to capture details such as mechanism of injury and time-loss. Indeed, a prospective study that recorded injury details from under-10s participating in conventional AF or with modified rules (i.e., Vickick), did not report injury-specific time-loss details.[37]

Unfortunately, there were no longitudinal studies, or studies that permitted sufficient comparisons, involving AF players as they progressed through different level-of-play. Thus, there are significant knowledge gaps regarding concussion rates over developmental periods. Identifying the extent of the

345 issue of concussion within AF is a necessary first step within the *sequence of prevention* framework.[66]
346 The recently updated version of this framework accommodates the *context* of sports injuries and
347 promotes preventative measures by incorporating factors at the individual, socio-cultural, and
348 environmental or policy level. This type of socioecological model has already been considered a viable
349 approach to preventing and managing sports-related concussion.[32] As such, implementing longitudinal
350 assessments in AF will help ensure head-impact exposure is considered in relation to the acute and
351 long-term consequences of concussive injuries, and with regard to contextual factors that influence the
352 ability to capture concussion incidence and implement concussion management protocols. As a result,
353 this approach will potentially shape public health initiatives focused on head-impact education,
354 prevention, and treatment.

355 The minimal exploration of head-impact exposure in AF[21,56] is unsurprising. Translating head-
356 impact data to represent meaningful clinical outcomes or physiological changes is in its infancy, with
357 recent findings failing to establish a link between biomechanical input and manifestations of concussion
358 in American Football players.[67] Although in its early stages, objectively capturing real-time head-
359 impact data, particularly in relation to player-specific outcomes, represents an important avenue for
360 future research.

361 Finally, while there are AFL sanctioned male and female competitions in other countries including
362 South Africa, Germany, and the United States, there were no studies conducted outside of Australia. As
363 AF is still an emerging sport in these countries, there is a potential risk of inexperienced coaching that
364 may inadvertently influence the risk of concussion for players. To help determine if geographical trends
365 exist and to permit comparison of AF-specific concussion management protocols, it is imperative that
366 concussion incidence and other injury trends are captured from international AF competitions.

367 While an extensive search across 14 databases using pre-defined criteria was conducted and the use
368 of broad search terms, particularly 'injury', reduced the likelihood of missing relevant studies, there are
369 limitations. While the overall risk-of-bias was low, studies that did not report concussion incidence in
370 a standardised format, or provide conversion data, were excluded, which may have impacted the results.
371 Nonetheless, even with concussion incidence rates in relation to player hours, we were still unable to
372 conduct a meta-analysis due to the heterogeneity of the data, and therefore relied on a narrative

synthesis. In addition, as the majority of studies were surveillance-based, follow-ups were infrequent. However, these studies provide a foundation for establishing the extent and nature of concussive injuries in AF, which is a necessary step toward isolating preventative measures. Employing etiological study designs in future research will promote follow-ups over extended periods and produce comparable data; this approach will help determine incidence rates and identify potentially modifiable contextual factors that contribute to the issue of concussion.

5. Conclusions

Current data collection practices fail to capture all concussions and do not include enough information about the concussions recorded, most notably RTP and mechanism of injury details. This has contributed to significant knowledge gaps regarding the incidence and nature of concussive impacts in AF across levels-of-play and has severely restricted the ability to: 1) make informed decisions about future participation in AF; 2) permit comparisons of risk across sports; and 3) monitor the effectiveness of concussion interventions and management protocols. We propose that future research efforts, including injury surveillance approaches and empirical studies, address the following: 1) promote accurate recording of all concussions and related details, including number of players, number of matches/training, mechanism of injury, and any time-loss (i.e., hours, days etc.) from sports-related activity; 2) explore the contextual factors that contribute to the incidence of concussive injuries in AF and influence RTP management; 3) determine if concussive injuries in AF are the result of AF-specific concussive mechanisms that may be amenable to intervention; 4) develop technologies that accurately capture head-impact kinematics in real-time, determine head-impact exposure rates, and promote objective RTP protocols; and 5) quantify the risk and severity of brain injury in AF by tracking these injuries over extended periods. Collectively, these approaches will help promote appropriate injury management and improve player outcomes.

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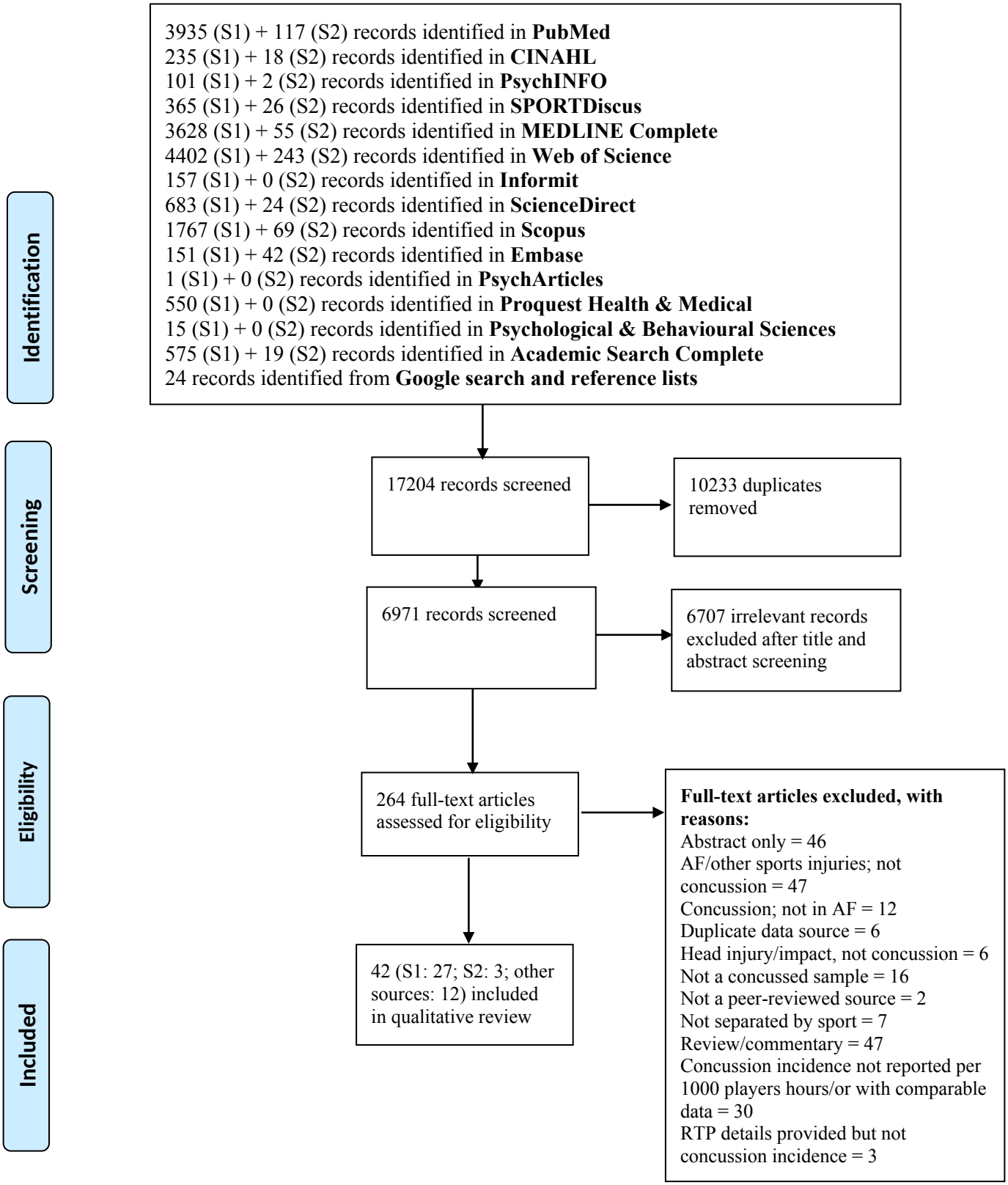
Supplementary Figure 1 PRISMA flow diagram



Note. AF: Australian football. RTP: Return-to-play. S1: Search 1 (18 May 2017). S2: Search 2 (8 April 2018).

Supplementary Table 1 PubMed Search Strategy

Concussion Terms		**Australian Rules football terms**
Concuss* OR concussion (MeSH Terms) OR brain OR brain (MeSH Terms) OR head OR head (MeSH Terms) OR craniocerebral OR craniocerebral (MeSH Terms) OR postconcuss* OR postconcussion (MeSH Terms) OR post-concuss* OR post-concussion (MeSH Terms) OR subconcuss* OR subconcussion (MeSH Terms) OR sub-concuss* OR sub-concussion (MeSH Terms) OR injur* OR injury (MeSH Terms) OR injured (MeSH Terms) OR injuries (MeSH Terms)	AND	"Australian football*" OR "Australian football" (MeSH Terms) OR "Australian football league" OR AFL OR "Victorian football league" OR VFL OR "Australian rules football" OR "Australian rules football" (MeSH Terms) OR "Australian rules" OR "Australian rules" (MeSH Terms) OR ARF OR Auskick

MeSH terms were explored in PubMed to identify additional relevant terms. Identical keywords were used in each database. Where possible, records were limited to 'Journal article' (or 'Article' or 'Academic Journal'), 'Peer-reviewed', 'English', and 'Human'. No date restrictions were applied for the first search (conducted on May 18, 2017). On April 8, 2018, an identical second search was conducted. Records were limited to those published from May 2017 to April 2018. Databases searched: Academic Search Complete, CINAHL, Embase, Informit, MEDLINE Complete, Proquest Health & Medical, Psychological & Behavioural Sciences Collection, PsychArticles, PsychINFO, PubMed, Science Direct, Scopus, SPORTDiscus, and Web of Science.

Supplementary Table 2 Risk-of-bias assessment based on ten criteria

Reference	Criteria										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Score**
Injury Surveillance Studies											
Ferguson et al. (1965) [33]	1	0	0	0	UD	1	0	1	0	1	4
Sali et al. (1981) [34]	1	1	1	1	1	1	0	1	0	1	8
Hoy et al. (1984) [35]	1	1	0	0	1	1	UD	1	UD	1	6
Dicker et al. (1986) [36]	1	1	0	0	1	1	UD	1	0	1	6
McMahon et al. (1993) [37]	1	1	1	1	1	0	1	0	UD	1	7
Seward et al. (1993) [38]	1	1	0	0	UD	1	UD	1	1	1	6
Shawdon et al. (1994) [39]	1	1	0	0	1	1	UD	1	0	1	6
Orchard et al. (1998) [40]	1	1	1	0	1	1	UD	1	1	1	8
Gabbe et al. (2002) [41]	1	1	1	0	1	1	1	1	0	1	8
Finch et al. (2002) [42]	1	1	1	1	0	1	1	0	1	1	8
Grimmer et al. (2003) [43]	1	1	1	1	UD	0	1	0	UD	1	6
Braham et al. (2004) [44]	1	1	1	0	UD	0	1	0	0	1	5
Braham et al. (2004) [45]	1	1	1	0	0	0	1	0	0	1	5
Romiti et al. (2008) [46]	1	1	0	0	1	0	1	0	UD	1	5
Twomey et al. (2012) [47]	1	1	0	1	1	0	1	0	1	1	7
Colby et al. (2014) [48]	0	1	1	0	1	1	1	1	1	1	8
Gibbs et al. (2017) [49]	1	1	0	1	1	1	UD	1	1	1	8
Lathlean et al. (2018) [50]	1	1	1	1	0	1	0	1	1	1	8
Total, n (%) of injury surveillance studies	18 (95)	18 (95)	10 (52)	8 (42)	12 (63)	13 (68)	10 (53)	11 (58)	8 (42)	19 (100)	**Ave:** 6.7
Reference	**Criteria**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Score**
Empirical Studies											
McCrory et al (2000) [51]	1	1	0	0	1	1	1	1	0	1	7
McCrory et al. (2000) [52]	1	1	0	1	1	1	1	1	1	1	9
Makdissi et al. (2009) [53]	1	1	1	1	1	1	1	1	1	1	10
Makdissi et al. (2010) [20]	1	1	1	0	1	1	1	1	1	1	9
Fortington et al. (2015) [54]	1	1[a]	1[b]	1	1	1	1	1	1	1	10
Makdissi et al. (2016) [55]	1	1	1	1	1	1	1	1	1	1	10
Total, n (%) of empirical studies	6 (100)	6 (100)	4 (67)	4 (67)	6 (100)	6 (100)	6 (100)	6 (100)	5 (83)	6 (100)	**Ave:** 9

Supplementary Table 2 cont. Risk-of-bias assessment based on ten criteria

Reference	Criteria										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Score**
AFL-Injury Report (AFL-IR)											
AFL-IR (2001) [4]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2002) [5]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2003) [6]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2004) [7]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2005) [8]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2006) [9]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2007) [10]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2008) [11]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2009) [12]	1	1	0	1	1	1	1	1	1	1	9
AFL-IR (2010) [13]	1	1	0	1	1	1	0	1	1	1	8
AFL-IR (2011) [14]	1	1	0	1	1	1	0	1	1	1	8
AFL-IR (2012) [15]	1	1	0	1	1	1	UD	1	1	1	8
AFL-IR (2013) [16]	1	1	0	1	1	1	UD	1	1	1	8
AFL-IR (2014) [17]	1	1	0	1	1	1	UD	1	1	1	8
AFL-IR (2015) [18]	0	1	0	1	1	1	UD	1	1	1	7
AFL-IR (2016) [19]	0	1	0	1	1	1	UD	1	1	1	7
Total, n (%) of AFL-IRs	14 (88)	16 (100)	0 (0)	16 (100)	16 (100)	16 (100)	9 (56)	16 (100)	16 (100)	16 (100)	**Ave:** 8.4
Combined results Total, n (%) of all categories	38 (93)	41 (98)	14 (34)	28 (68)	34 (83)	35 (85)	25 (61)	33 (80)	29 (70)	16 (100)	**Ave:** 7.7

Reference	Criteria										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Score**
Head-impact exposure studies[c]											
King et al. (2017) [56]	NA	1	1	0	UD	UD[d]	1	NA	0	1[e]	4 (8)
Wilmott et al. (2017) [21]	NA	1	1	0	0	1[f]	1	NA	0	1[e]	5 (8)
Total, n (%) of head-impact exposure studies	NA	2 (100)	2 (100)	0 (0)	0 (0)	1 (50)	2 (100)	NA	0 (0)	0 (100)	**Ave:** 4.5

Note. Risk of bias scores: low = 1, high = 0, UD = unable to determine; counted as 0 in the score. Ave: average. NA: Not applicable; excluded from final calculation. [a]Secondary analysis of prospectively collected injury data. [b]Details provided in previous publications. [c]Scored out of 8 not 10. [d]Not reported if any of the players involved sustained a concussion during the data collection period. [e]Details on head-impact exposure provided. [f]Noted that no player sustained a concussion.

Criteria[57]

1. Definition of injury clearly described
2. Prospective design that presents incidence or prevalence data
3. Description of Australian football players (e.g. age and level-of-play; gender was also considered specifically for this review)
4. The process of inclusion of athletes in the study was at random (i.e., not by convenience) or the data collection was performed with the entire target population
5. Data analysis performed with at least 80% of the athletes included in the study
6. Injury data reported by players or by a healthcare professional
7. Same mode of injury data collection used
8. Injury diagnosis conducted by medical professional
9. Follow-up period of at least 6 months – for this review, this criterion was interpreted as the sample being followed for at least 6 months (e.g., following players from the same club or competition over at least 6 months), as opposed to a follow-up of period of at least 6 months post-concussion
10. Incidence or prevalence rates of injury expressed by a ratio that represents both the number of injuries as well as the exposure to Australian football (i.e., number of injuries/hours of Australian football exposure, or number of injuries/matches of Australian football exposure)

Supplementary Table 3 Summary of Injury Surveillance Studies and Empirical Studies that Reported Concussion Incidence per 1000 hours or Provided Sufficient Data for Conversion

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[33] Ferguson (1965)	Retrospective review of injuries from one Victoria Football League club; presented by the author (a medical officer for a VFL club).	**Sex:** Male[a]. **Age:** U17 to adult
Aims/Purpose: Not explicitly stated. Broadly, for the author to detail his experiences with injury as a *Medical Officer of the Victoria Football League.* **Level of play:** Unclear; includes players that *passed through* the authors VFL club. Players were across five teams from the an U17s competition to the open age group, and all had participated in at least 5 games each. **Injury definition and diagnosis:** Reported two classes of injuries: *1) injuries to soft tissue, including muscles, ligaments, blood vessels and some important organs such as liver, bowel, lungs and kidneys; 2) injuries to bones and joints, further divided into two classes: a) fractures and dislocations; b) ligamentous injuries*. **Concussion definition:** *As determined by loss of consciousness, amnesia, disorientation or visual dysfunction.* Assumed the club doctor (author of the article) diagnosed all players. **Possible-time-loss** (time-loss not mentioned). **Recorded:** **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Number of players:** approximately 2600. **Number of injured players:** NR. **Player hours:** 13,000 (match). **Total injuries**: 792 (only reported those that required active medical treatment), including 21 concussions. **Total injury incidence rate[b]:** 60 per 1000 player hours (estimated as total number of players was estimated; 95% CI, 56.79-65.28). **Concussion incidence rate[b]:** 1.62 per 1000 player hours (95% CI, 1.03-2.43). **Concussion ranking among other injuries**: Ranked 7th of 34 injuries; 2.65% of total injuries.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[34] Sali, McColl, & Dicker (1981)	Prospective cohort study.	**Sex:** Male[a] **Age:** NR
Aims/Purpose: Report on the extent of injuries among senior players in the VFL during one season. **Level of play:** VFL. 1979 season (22 weeks; finals, night matches and pre-season games excluded). **Injury definition and diagnosis:** *An injury was defined as a condition sustained following trauma during game play which satisfied these requirements: 1) the injury had to come to the attention of the club medical officer; 2) required active treatment; 3) resulted in one or more of the following :a) exclusion from play for the rest of the game; b) interference with one or more training sessions; c) exclusion from one or more subsequent games.* Diagnosed by club medical officers. Players had to participate in one or more first grade day-time fixtures to be included. **Possible time-loss.** **Recorded:** **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Number of players:** 449. **Number of injured players:** 256. **Player hours:** reported as 11,040 person-risk hours. **Total injuries**: 531; 123 head and neck injuries, including 30 concussions; **Total injury rate:** 1 injury per 21 person-risk hours. **Total injury incidence rate[b]:** 48.10 per 1000 player hours (95% CI, 44.14-52.32) **Concussion incidence rate[b]**: 2.72 per 1000 player hours (95% CI, 1.87-3.83). **Concussion ranking among other injuries**: Concussion ranked 6th of 21 injury types (based on number of injuries); comprised 6% of all injuries		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[35] Hoy & Kennedy (1984)	Prospective cohort study.	**Sex:** Male[a]. **Age:** NR
Aims/Purpose: To observe and record the natural history of injuries to senior Australian Rules Footballers of a Victorian Football Association club, Prahan in the 1981 season. **Level of play:** Community; seniors. 1981 Victorian Football Association season. **Injury definition and diagnosis:** *To qualify, the injury: 1) had to come to the attention of the club medical officers; 2) required active treatment by the medical staff; and 3) restrict the player's training or game performance*. **Concussion definition:** As defined by the Royal Australian College of Surgeons; details not provided. Diagnosed by medical officers. **Possible-time-loss** (time-loss may be more or less than 24 hours of restricted participation).		

Recorded: **Mechanism of concussive injury:** N (reported at the total injury level). **Concussion specific time-loss/RTP time-frames:** N (missed games and time lost from sport/occupation reported at total injury level). **Sample:** **Number of players:** 58. **Number of injured players:** 36. **Player hours:** reported as 2,572 person-risk hours. **Total injuries**: 91; 21 head and neck injuries, including 8 concussions; **Total injury rate:** 1 injury per 28 person-risk hours**. Total injury incidence rate[b]:** 35.38 per 1000 player hours (95% CI, 28.65-43.24). **Concussion incidence rate[b]:** 3.11 per 1000 player hours (95% CI, 1.45-5.91). **Concussion ranking among other injuries**: Concussion ranked 6th of 13 (based on type of injury); comprised 9% of all injuries. Noted that 40 injuries resulted in 128 games missed; 89 games missed due to severe injury; average of 1.4 games per injury.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[36] Dicker, McColl, & Sali (1986)	Prospective study.	**Sex:** Male[a]. **Age:** NR.
Aims/Purpose: To report on the site and nature of injuries over a three-year (non-consecutive) period in Australian Rules football. **Level of play:** VFL; 12 VFL clubs in 1979, and 11 VFL clubs in both 1980 and 1982. **Injury definition and diagnosis:** *An injury was defined as a traumatic condition sustained during game play, which came to the attention of the club medical officer, required active treatment, and interfered with subsequent play or training.* **Possible time-loss** (i.e., 'subsequent play' play could refer to game-play on the day of injury or subsequent games). **Recorded:** **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Number of players:** 1287. **Number of injured players:** 676. **Player hours[c]:** 29,568 player hours **Total injuries:** 1408; 270 head and neck injuries, including 74 concussions; **Total injury incidence rate[b]:** 47.61 per 1000 player hours (95% CI, 45.18-50.16). **Concussion incidence rate[b]:** 2.50 per 1000 player hours (95% CI, 1.98-3.12). **Concussion ranking among other injuries:** Ranked 5th of 7 injuries (based on type of injury). 5% of total injuries.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[37] McMahon, Nolan, Bennett, & Carlin (1993)	Prospective cohort study.	**Sex:** 1236 males; and 17 females (all females in Vickick). **Age:** U10 to U18
Aims/Purpose: To ascertain the incidence, severity, risk factors, and outcomes of injuries in children and adolescents playing Australian Rules football. **Level of play:** Community level (children and adolescents). 54 teams; 1992 (excluding finals). **Injury definition and diagnosis:** *Any trauma that caused some disability or pain*. Two further restricted definition were applied: *Injuries that interfered with normal functioning during training, game, school, or leisure; or requiring consultation with a health professional* (classified as *injuries with functional impairment)*. Data entry by trained volunteers. **Possible-time-loss** (time-loss may be more or less than 24 hours of restricted participation). **Recorded (Y/N):** **Mechanism of concussive injury:** N (reported at the total injury level). **Concussion specific time-loss or RTP time-frames:** N (median days lost reported at the total injury level) **Sample:** 54 teams and clinics. 18 U15 teams, 18 U10 teams (conventional competitions), 18 Vickick clinics for children U10 (modified rules). 17 (1.4%) were girls. Injuries not broken down by sex. **Total number of players:** 1253. **Total player hours:** 30,459. **Total number of injured players:** 200. **Total number of injuries:** 246, including 15 concussions (3 not attributed to any age group; UD if they occurred in the U10 teams or in the Vickick clinics). **Total injury incidence rate[b]:** 8.08 per 1000 player hours (95% CI, 7.11-9.14) **Total concussion incidence rate[b]:** 0.49 per 1000 player hours (CI, 0.29-0.79). UD if the remaining 3 concussions occurred in players participating in a conventional competition, or in the Vickick clinics with modified rules. **U15 number of players:** 565. **U15 number of injured players:** 147. **U15 player hours:** 15,024. **U15 total injuries:** 147, including 12 concussions (8.16%). **U15 injury incidence rate:** 9.79 per 1000 player hours (CI, 8.2-11.37). **U15 concussion incidence rate[b]:** 0.80 per 1000 player hours (95% CI, 3.47-12.51). **Concussion ranking among other injuries:** Overall: Ranked equal 6th of 10 injuries (based on injury type). 6% of total injuries (based on injury type). Noted that 8% of younger children wore head protection. 30% of all injuries involved consultation with a health professional; 10% of these were for concussion		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[38] Seward, Orchard, Hazard, & Collinson (1993)	Prospective cohort study.	**Sex:** Male[a]. **Age:** NR

Aims/Purpose: To determine injury profiles for the elite level competitions of football played in Australia.
Level of play: AFL; seniors and reserves (included NSWRL and NSWRU - not reported here). 1992 season (22 matches per club over 24 rounds); 12 clubs, 23 teams.
Injury definition and diagnosis: *Any injury which caused a player to be unavailable for selection in a match, or participation in a training session; or any other injury which required specific medical treatment, other than routine conservative measures (e.g., concussion, lacerations, finger dislocations which may not necessarily have caused matches or training to be missed).* Data entry by club doctor. **Possible-time-loss**.
Recorded (Y/N): **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N (missed hours reported at the total injury level for first injury (183 hours missed per 1000 player hours) and all injuries (179 hours per 1000 player hours).
Sample: **Total number of players:** NA. **Total number of injured players**: NA. **Total injuries:** 941 (all injuries); 542 (first injury); concussions comprised 3.6% (34 concussions; assumed part of 'all injuries'). **Player hours[c]:** 15,177. **Total injury incidence rate all injuries:** 62 per 1000 player hours (time loss and no time loss; (95% CI, 58.13-66.06). **Total injury incidence rate first injury:** 68 per 1000 player hours (time loss and no time loss. **Total injury incidence rate all injuries:** 34 per 1000 player hours (time loss). **Total injury rate first injury:** 35 per 1000 player hours (time loss). **Concussion incidence rate[b]:** 2.24 per 1000 player hours (95% CI, 1.58-3.10). **Concussion ranking among other injuries:** Ranked 6th of 10 injuries (based on frequency of injury).

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[39] Shawdon & Brukner (1994)	Prospective cohort.	**Sex:** Male[a]. **Age:** NR

Aims/Purpose: To document over one season the injury profile of one amateur ARF club and to compare this with the rates of injury previously documented for elite AFL competition. **Level of play:** Community level; amateur (seniors and reserves)**.** 1993 season (18 weeks). One VAFA club. **Concussion/injury definition and diagnosis:** *Injuries reported included those that necessitated missing at least one game, plus all fractures, lacerations, and concussions that came to the attention of the club doctor.* Recorded by club doctor. **Possible time-loss** (concussion considered in the 'plus' category).
Recorded (Y/N): **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N (missed games reported at broad level).
Sample: **Total number of players:** 80. **Total number of injured players:** NR. **Total injuries:** 52, including 8 concussions. **Player hours[c]:** 541.67. **Total injury incidence rate:** 96 per 1000 match hours (95% CI, 72.44-124.90). **Concussion incidence rate[b]:** 14.76 per 1000 match hours (95% CI, 6.86-28.05). Unclear if concussion diagnosis required a game to be missed, as listed in a separate category of 'injury'. Also noted that the 'majority of cases were mild and did not cause a subsequent game to be missed'; it is unclear if this means some cases were not mild and did result in a missed game(s). **Concussion ranking among other injuries:** Ranked 1st of 19 injuries (based on the nature of the injury). 15% of all injuries.

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[40] Orchard (1998)	Prospective cohort study.	**Sex:** Male[a]. **Age range:** 17 to 33; *M* = 22. Age distribution of injury specifics NR.

Aims/Purpose: To document the way in which injuries in the AFL have been managed by their club medical staff. **Level of play:** AFL. 1 club. 4 seasons. 1994 to 1997.
Injury definition and diagnosis: *An injury was defined as any symptomatic presentation to a club doctor, who was present at all club games, training sessions and injury clinics.* Diagnosed by club doctor. **Possible-time-loss** (time-loss not mentioned).
Recorded (Y/N): **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** Y. 16 competition matches missed; 0 pre-season matches missed. NR how many concussive injuries resulted in missed matches.
Sample: **Number of players:** 86. **Number of injured players:** NR. **Player hours[c]:** 5895.27. **Total injuries:** 2308 injuries; 224 head and neck injuries, including 70 concussions. **Total injury incidence rate:** 391.5 per 1000 player hours (95% CI, 375.80-407.70). **Concussion incidence rate[b]:** 11.87 per 1000 player hours (95% CI, 9.33-14.91). **Concussion ranking among other injuries:** Ranked 7th of 22 injuries (based on injury category).

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[41] Gabbe, Finch, Wajsweiner, & Bennell (2002)	Prospective cohort study	**Sex:** Male. **Injured players – Age range:** 17.3 to 34.8; median = 22.9.

Aims/Purpose: To develop and trial an injury surveillance system that can be used by community level Australian football clubs; and to describe the epidemiology of injuries sustained by community level Australian football players, including exposure-adjusted injury rates. **Level of play:** Community level; amateur (seniors and reserves) 1999 season (18 rounds). Five clubs from the VAFA. **Injury definition and diagnosis (by whom) (note if time-loss; possible time-loss; non-time-loss):** *Any injury that resulted in missed training time (one or more sessions) and/or missed competition time (including leaving the ground to allow an injury to be attended to) and/or required treatment from a health professional.* Data collection forms completed when player first consulted a club medical staff member (physiotherapist, medical practitioner or sports trainer) for their injury. **Possible time-loss:** (and/or implies an injury could require medical treatment without missing a training session or game).
Recorded (Y/N): **Mechanism of concussive injury:** N (reported at total injury level). **Concussion specific time-loss or RTP time-frames:** N.
Sample: **Total number of players:** 320. **Total number of injured players:** NR. **Total injuries:** 421 (only 350 injury cases recorded on data collection forms); 11 concussions (3.14% based on 350 injuries). **Player hours[c]:** 12,867.64. **Total injury incidence rate:** 27.2 per 1000 match/training hours (95% CI, 24.46); 52.8 per 1000 match hours; 6.5 per 1000 training hours. **Concussion incidence rate[b]:** Not stated if concussions occurred in matches or training; calculated based on total injury rate): 0.85 per 1000 match/training hours (95% CI, 0.45-1.49).
Concussion ranking among other injuries: Ranked equal 6th of 10 (based on the top 10 most common provisional diagnoses, which represent 53.4% of cases).

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[42] Finch, Da Costa, Stevenson, Hamer, & Elliott (2002)	Prospective study.	**Sex:** AF-specific: Male. **Age range:** 9 to 45+; *M* = 23; *SD* = 4.7.

Aims/Purpose: To describe the incidence of injury over two consecutive sporting seasons in a prospective cohort of community-level sporting participants within the four sports of Australian football, hockey, basketball and netball. **Level of play:** Community. May-September 1997 and May-September 1998. **Injury definition and diagnosis (by whom) (note if time-loss; possible time-loss; non-time-loss):** *A sports injury was defined according to the Council of Europe definition as one that occurred while participating in sport and 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. Injuries were graded as minor (requiring self-treatment only), moderate (requiring health care attention) or severe (requiring hospital admission).* Players self-reported injuries. **Possible time-loss** (reduction in participation may be more or less than 24 hours).
Recorded (Y/N): **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N.
Sample: **Number of players:** ARF specific: 547 recruited; 321 followed up more than 7 times. **Number of injured players:** ARF specific: 274. **Player hours[c]:** 36,218.91 **Total injuries:** ARF specific: 728 including 18 concussions. **Total injury incidence rate:** ARF specific: 20.1 per 1000 exposure (games/training) hours (95% CI, 18.68-21.60). **Concussion incidence rate[b]:** 0.50 per 1000 games/training hours (95% CI, 0.30-0.77). **Concussion ranking among other injuries:** ARF specific: Ranked equal 6th of 10 injuries (based on nature of injury). ARF specific: 6.6% of total injured players.

Reference	Study design	Sample: Sex. Age (range, mean, SD [years])
[43] Grimmer & Williams (2003)	Prospective cohort study	**Sex:** Male. **Age range**: 7 to 17.

Aims/Purpose: To report on injuries sustained by Australian Rules footballers aged 7 to 17 who played a full season of junior South Australian National Football League affiliated school or club competition in 2000. **Level of play:** Junior football South Australian National Football League (SANFL). 2000 season. **Injury definition and diagnosis:** *Anything that significantly interferes with enjoyment of sport may involve time-loss but not necessarily*. Recorded by nominated team parent, teacher, or coach. **Possible-time-loss.**
Recorded (Y/N): **Mechanism of concussive injury:** N (reported at the total injury level). **Concussion specific time-loss or RTP time-frames:** N.
Sample: **Total sample of** 373 teams. 21 randomly selected clubs and schools. 16 clubs/schools provided pre-season data. 10 clubs and schools provided season-long data. 136 players reported 234 injuries.
Total number of players: 697 **Total number of injured players:** 136 **U13 number of players:** 87 **U13 number of injured players**: 21
U13 player hours[c]: 4629.63 **U13 total injuries:** 50; 2 concussions (4%) **U13 total injury incidence rate:** 10.8 per 1000 player hours (95% CI, 8.10-14.12)
U13 concussion incidence rate[b]: 0.43 per 1000 player hours (95% CI, 0.07-1.43) **U15 number of players:** 183 **U15 player hours[c]:** 7034.48

U15 number of injured players: 51 **U15 total injuries:** 102; 4 concussions (3.9%) **U15 total injury incidence rate:** 14.5 per 1000 player hours (95% CI, 11.88-17.53) **U15 concussion incidence rate[b]**: 0.57 per 1000 player hours (95% CI, 0.18-1.37). **Concussion ranking among other injuries:** Not specifically stated. The percentage of total players who sustained injuries to specific body parts was greatest to the skull/head/face in U13s; this body region was ranked 4th highest in U15s.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[44] Braham, Finch, & McCrory (2004)	Prospective cohort study	**Sex:** NR. **Age:** *M*= 22.3.
Aims/Purpose: The aim of this short report is to present the exposure-adjusted incidence of head/neck/orofacial (H/N/O) injuries in a cohort of community level of Australian Football players for the first time. Part of the AFIPP. **Level of play:** Community level (seniors/reserves). Victoria. 2001 season. **H/N/O injury definition and diagnosis:** *Head injuries included any injury to the forehead, scalp, ears, skull or brain or face.* Trained primary data collectors for each team recorded data. **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N):** **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Total number of players:** 294 (from 23 teams who did not wear protective headgear). **Total number of injured players:** 37. **Player hours[c]:** 14,230.77. **Total number of injuries:** 37 H/N/O injuries including 7 concussions during games (18.9%); 0 during training. **HNO incidence rate:** 2.6 per 1000 participation hours (games and training; 95% CI, 1.86-3.55) **Concussion incidence rate:** 0.49 per 1000 game hours (95% CI, 0.22-0.97). **Concussion ranking among other injuries:** Ranked 2nd of 8 H/N/O injuries (based on most common H/N/O injury).		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[45] Braham, Finch, McIntosh, & McCrory (2004) Same sample as [66] but concussion incidence based on entire sample not only those who did not wear protective head-gear.	Review of data from a RCT.	**Injured players - Sex:** NR. **Age:** *M* = 22.5. **Uninjured players - Sex:** NR. **Age:** *M* = 22.1.
Aims/Purpose: To describe the injury profile of community level football players participating in a metropolitan football league during one player season. Part of the AFIPP, a RCT that assessed the effectiveness of protective headgear and mouthguard use. **Level of play:** Community level; amateur (seniors, reserves, U18s and U16s). 2001 season (18 rounds for seniors/14 rounds for juniors). **Injury definition and diagnosis:** *A player was defined to be injured if a) he could not complete a training or session or game; b) he missed an entire training session or game; or c) if he received treatment either during the session or immediately after the session by support staff (e.g., a doctor or sports trainer).* Injuries coded according to the Australian Sports Injury Data Dictionary. All injuries that occurred during training and games were recorded by a trained primary data collector. **Possible time-loss.** **Recorded (Y/N):** **Mechanism of concussive injury:** N (reported at the total injury level). **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Total number of players:** 301 (from 23 teams; 63.5% response rate). **Total number of injured players:** 116. **Player hours[c]:** 17355.37. **Total injuries:** 210; 4.3% concussions; 9 concussions. **Total injury incidence rate:** 12.1 per 1000 match/training hours (95% CI, 10.54-13.82). 20.5 per 1000 match hours. **Training:** 5.8 per 1000 hours. Not reported if concussions occurred during matches or training. **Concussion incidence rate[b]:** 0.52 per 1000 match/training hours (95% CI, 0.25-0.95). **Concussion ranking among other injuries:** Ranked equal 5th of 6 injuries (based on top 6 most commonly reported injuries, which comprised 78.6% of all injuries). 4.3% of most commonly reported injuries.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[46] Romiti, Finch, & Gabbe (2008)	Prospective cohort study	**Sex:** NR. **Age:** U9 to U18.
Aims/Purpose: To determine the rate of injury in junior Australian football, and to describe the patterns and severity of these injuries across nine levels of play (U9 to U18) **Level of play:** Community; junior (U9, U10, U11, U12, U13, U14, U15, U16, U18). 51 teams from NSW and VIC. 2004 playing season. **Injury definition and diagnosis:** *An injury was any trauma causing disability and/or pain. Injury severity was based on the immediate action or, and advice offered to injured players*. PDC recorded during training sessions and games by nominated parents, coach, trainer, or team manager. **Possible-time-loss** (time-loss not mentioned).		

Recorded (Y/N): **Mechanism of concussive injury:** N (reported at the broad injury-category level). **Concussion specific time-loss or RTP time-frames:** N **Sample:** **Total number of players:** NR. **Total number of injured players:** NR. **Player hours[c]:** 39,722.22 **Total injuries:** 715; 66 head injuries (9.2% of injuries); 14 concussions (21.2% of head injuries; 1.96% of total injuries). **Total injury incidence rate:** 18 per 1000 match and training hours (95% CI, 16.72-19.36). **Concussion incidence rate[b]:** 0.35 per 1000 match and training hours (95% CI, 0.20-0.58); NR as a function of age group. **Head injury:** U9 48players: 16.7%; U10 (39 players): 0%; U11 (64 players): 12.5%; U12 (67 players): 11.9%; U13 (125 players) and U14 (38 players): 0%; U15 (52 players): 0%; U16 (77 players): 0%; U18 (205 players): 0%. **Concussion ranking among other injuries:** NR. Head injury ranking based on top three regions of injury: U9, 2nd; U10, not in the top 3; U11, equal 2nd; U12, equal 3rd of 4 regions; U13, not in the top 3; U14, not in the top 3; U15, not in the top 3; U16, not in the top 3; U18, not in the top 3.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[47] Twomey, Finch, Lloyd, Elliot, & Doyle (2012)	Prospective injury surveillance.	**Sex:** NR. **Age:** 18 and over.
Aims/Purpose: To describe the risk and details of injuries associated with ground hardness in community level Australian football. **Level of play:** Community level: 10 senior and 10 research grade teams in Victoria and 8 senior, 7 reserves, and 5 U/19 grade teams in Western Australia. 2007 and 2008 seasons. Part of a large RCT called (PAFIX) **Injury definition and diagnosis:** *An injury was defined as that which caused a player to seek medical attention on the ground or on leaving the ground (from a sports trainer through to medical doctor). Time-loss injury severity definition used and coded at three levels: player did not leave the field; player left the field but returned to play later in the game; player left the field and was unable to return to play in the same game.* Data recorded by trained primary data collectors. **Possible time-loss.** **Recorded (Y/N):** **Mechanism of concussive injury:** N (reported at the total injury level). **Concussion specific time-loss or RTP time-frames:** N **(**RTP details for time-loss on the day of the injury included in details of injury severity; details NR at the specific injury level). **Sample:** **Number of players:** NR. **Number of injured players:** NR. **Player hours[c]:** 8979.59. **Total injuries:** 402 injuries (165 in 2007; 237 in 2008); only 352 related to ground hardness. 14 concussions related to ground hardness: Unacceptably low: 0; low/normal: 6; preferred range: 6; high/normal: 2; unacceptably high: 0. **Total injury incidence rate:** 39.2 injuries per 1000 player hours (95% CI, 35.26-43.46). **Concussion incidence rate[b]:** 1.56 per 1000 player hours (95% CI, 0.89-2.55) **Concussion ranking among other injuries:** Ranked 7th of 7 injuries (based on nature of injury).		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[48] Colby, Dawson, Heasman, Roglaski, & Gabbett (2014)	Prospective cohort study.	**Sex:** Male[a]. **Age:** *M* = 25.1; *SD* = ± 3.4.
Aims/Purpose: The purpose of this study was to investigate the relationship between overall physical workload (GPS/accelerometer) measures and injury risk in elite AFL players during a season. **Level of play:** AFL and WAFL. One club. 2012 pre-season and in-season (18 matches) **Injury definition and diagnosis**: No specific definition provided. *Injuries were classified as being either low severity (the player was given modified training and did not miss a game), and/or moderate severity (the player missed 1-2 weeks of training and missed 1-2 games) and/or high severity (the player missed > 2weeks of training and missed > 2 games).* The senior physiotherapist classified all injury information and updated the database. Injury type, body site, and mechanism were recorded. **Possible time-loss.** **Recorded (Y/N):** **Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample:** **Total number of players:** 46. **Total number of injured players:** NR. **Total player hours:** 30,459. **Pre-season player hours:** 1405.8. **In-season player hours:** 1700.4. **Total number of injuries:** 297 (110 pre-season; 187 in-season); 13 concussions (4 pre-season; 9 in-season) (4.38%). **Pre-season injury incidence rate:** 78.25 per 1000 hours (95% CI, 64.62-93.94). **In-season injury incidence rate:** 110 per 1000 hours (95% CI, 95.04-126.60). **Pre-season concussion incidence rate:** 2.85 per 1000 hours (training and game) (95% CI, 0.90-6.86). **In-season concussion incidence rate:** 5.29 per 1000 hours (training and game) (95% CI, 2.58-9.71). **Total concussion incidence rate:** 4.19 per 1000 hours (training and game) (95% CI, 2.33-6.98). Concussion incidence based on severity (e.g., missed games) not specified. **Concussion ranking among other injuries:** Overall concussion incidence rate ranking based on injury type: equal 4th of 7.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**

[49] Gibbs & Watsford (2017)	Prospective cohort study	**Sex:** Male[a]. **Age:** NR.
Aims/Purpose: To provide an accurate synopsis of concussion incidence in the AFL and its relationship to a number of variables. **Level of play:** AFL. One club over 14 years. 2000 to 2013 seasons. **Concussion definition and diagnosis:** *Concussion was defined as the immediate and transient impairment of neural function. Recurrent concussion was defined as any subsequent concussion injury that occurred after a player had returned to full team participation from the index concussion*. Diagnosed by club doctors. **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N): Mechanism of concussive injury:** N; **Concussion specific time-loss or RTP time-frames:** Y; 27 did not return to play in the same game; 113 did: 48 to play for 1Q; 32 to play for 2Qs; 33 to play for 3Qs. all players reviewed 24-48hrs post game and rested for a minimum 72hours). No player missed the following week's match due to concussion. **Sample: Total number of players**: 116. **Total number of injured players:** 45. **Total injuries:** NA; 140 concussions. All hours are for match time (each match involved 18 players on the field at one time for a total of 1.33hrs). **Total player hours:** 7972.02. **Regular season player hours:** 7373.52. **Finals player hours:** 598.5. **Day match hours:** 4381.02. **Night match hours:** 3591. **Wet condition hours:** 1244.88. **Dry condition hours:** 6727.14. **Total injury incidence rate:** NA. **Total concussion incidence rate:** 17.56 (95% CI, 14.83-20.66). **Regular season concussion incidence rate:** 130 concussions. 17.63 per 1000 player hours (95% CI, 14.79 - 20.86). **Finals:** 10 concussions. 16.71 per 1000 player hours (95% CI, 8.49-29.78). **Day matches:** 73 concussions. 16.66 (95% CI, 13.16 - 20.83). **Night matches:** 67 concussions; 18.66 per 1000 player hours (95% CI, 14.57-23.55). **Wet conditions:** 13 concussions; 10.44 per 1000 player hours (95% CI, 5.81-17.41). **Dry conditions:** 127 concussions;18.88 per 1000 player hours (95% CI, 15.80-22.38). No persistent post-concussion symptoms reported (details of symptoms NR). **Concussion ranking among other injuries:** NA; only focused on concussion. 12% involved LOC and 80.7% cleared and RTP in the same game. Strong relationship between matches played and concussion incidence (r = .70). **Recurrent concussion incidence**: 5.37 per 1000 player match hours (95% CI, 0.14-29.93); based on one player sustaining a recurrent concussion in the subsequent match.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[50] Lathlean, Gastin, Newstead, & Finch (2018)	Prospective cohort data	**Sex:** Male[a]. **Age range:** 16 to 18; M = 17.7; SD = ± 0.3 years.
Aims/Purpose: To describe the incidence, prevalence, severity, mechanism, and body region of injuries in elite junior AF players over one competitive season in order to help inform injury prevention interventions. **Level of play:** U18 state league (TAC Cup). 9 teams. 2014 season. **Injury definition and diagnosis:** *An injury was recorded if the injury event led the player to miss a full training session or match. Injuries were classified according to three categories: 1) new injury: 'a traumatic injury event that was not related to a previous injury'; 2) re-injury: 'a traumatic injury related to a previous injury event which occurred after a full recovery from the initial injury'; 3) exacerbation: 'an acute onset re-aggravation of a current injury or re-injury before full recovery from the index injury.* Injury severity categorised as: 1) slight (1 day); 2) minimal (2-3 days); 3) mild (4-7 days); 4) moderate (8-28 days); 5) severe (>28 days). Players and staff members entered injury details online and information was crosschecked with medical and support staff. **Time-loss.** **Recorded (Y/N): Mechanism of concussive injury:** N (reported at the broad injury-category level); **Concussion specific time-loss or RTP time-frames:** N (RTP details reported at the broad injury level). **Sample: Total number of players:** 562. **Total number of injured players:** 449. **Player hours[c]:** 32043.01. **Total injuries:** 1192; 64 head injuries (5% of total injuries) including 6 concussions (0.5% of total injuries). NR if concussions occurred during match or training. **Total injury incidence rate:** 37.2 per 1000 match/training hours (95% CI, 35.13-39.36). **Concussion incidence rate[b]:** 0.19 per 1000 match/training hours (95% CI, 0.08-0.39). Average of 2.7 injuries per player. **Head injuries:** 38 from contact, 28 from being intentionally struck by another player. Mean severity for head injuries: 10 days (95% CI 7-14 days), however four of these were considered severe with 37 days away from training or competition. **Concussion ranking among other injuries:** UD.		
Reference; Category	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[51] McCrory, Ariens, & Berkovic (2000)	Prospective cohort study	**Sex:** Male[a]. **Age:** NR.

Post-concussion assessment		
Aims/Purpose: To document the nature and temporal profile of the clinical symptoms of acute sport-related concussion. **Level of play:** AFL. 20-week season. **Concussion definition and diagnosis:** Concussion was *defined according to the standard Congress of Neurological Surgeons definition 'as a clinical syndrome characterised by the immediate and transient post-traumatic impairment of neural function such as alterations of consciousness, disturbance of vision or equilibrium due to mechanical forces.'* Team medical staff completed all assessments. **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N): Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** Y (10 returned the day of concussion; 6 returned by day 7; 7 returned by day 14). **Sample: Total number of players**: 303. **Total number of injured players:** 23. **Player hours[c]:** 6969.70. **Total injuries:** NA; 23 concussions. **Total injury incidence rate:** NA. **Concussion incidence rate:** 3.3 per 1000 player hours (95% CI, 2.14-4.87). **Concussion ranking among other injuries:** NA; only focused on concussion.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[52] McCrory & Berkovic (2000) *Video analysis*	Retrospective video review	**Sex:** Male[a]. **Age:** NR.
Aims/Purpose: To describe the motor and convulsive manifestations in acute sports-related head injury. **Level of play:** AFL. 1995-1997 seasons. **Concussion definition:** defined in terms of *medically diagnosed and injury severity information such as LOC, presence of retrograde and anterograde amnesia, or both.* Concussive injuries identified from the AFLMO Injury Survey Database. **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N): Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** N. **Sample: Total number of players**: 303. **Total number of injured players:** NR. **Player hours[c]:** 7187.50 **Total injuries:** NA; 23 concussions. **Total injury incidence rate:** NA. **Concussion incidence**: 3.2 per 1000 player hours (95% CI, 2.08-4.73). **Concussion ranking among other injuries:** NA; only focused on concussion.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[53] Makdissi, McCrory, Ugoni, Darby, & Brukner (2009)	Prospective cohort study	**Concussed group:** 138 males. *M* = 24.7 **Control group:** 138 males, *M* = 24.6
Aims/Purpose: To determine whether a concussed player returned to play using an individual clinical management strategy is a risk of impaired performance or increased risk of injury or concussion. **Level of play:** AFL. 4 seasons; 2000-2003. **Concussion definition:** Diagnosis made by team doctors at each club using standard injury definitions. Verified with media injury reports and information obtained from the independent prospective injury database that records all injuries occurring in the AFL. *Criteria contributing to the identification of concussed players included symptoms reported by players or signs observed by medical staff after a traumatic injury. Symptoms included (but were not limited to) players reporting feeling dinged, dazed, stunned, woozy, foggy, "head full of cotton wool" or "not quite right" as well as posttraumatic headache, visual disturbance, confusion, memory disturbance, balance disturbance, vertigo, and light headedness. Signs included confusion, loss of consciousness, disorientation, memory disturbance, unsteadiness, attention deficit, and personality change.* **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N): Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** Y; 127 (92%) RTP without missing a game; 11 (8%) RTP missed one game. **Sample: Total number of players**: 158. **Total number of injured players:** NR. **Player hours[c]:** 24642,86. **Total injuries:** NA; 199 concussive injuries occurred; analyses conducted on 138. **Total injury incidence rate:** NA. **Concussion incidence rate:** 5.6 per 1000 player hours (95% CI, 4.72-6.60). **Concussion ranking among other injuries:** NA; only focused on concussion.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**

[20] Makdissi, Darby, Maruff, Ugoni, Brukner & McCrory (2010)	Prospective cohort study	**Sex:** Male. **Overall age range:** 16 to 35; median age: 22 (IQR 19-24) **Concussed players:** median age: 22 years (IQR, 17-34years) **Concussed group:** 78 (88 concussions). From a sample of 1015 (675 elite-senior; 272 elite-junior; 68 community-level).
Aims/Purpose: To describe the pattern of symptom and cognitive recovery after concussion in Australian football and to investigate the relationship between these features and time to RTP, in order to identify clinical factors that may be useful in classifying injury severity. **Level of play:** Elite-senior, elite-junior, community. 4 seasons; 2001-2004. **Concussion definition:** Diagnosis made by team doctors at each club using standard injury definitions. **Possible-time-loss** (time-loss not mentioned). **Recorded (Y/N): Mechanism of concussive injury:** N. **Concussion specific time-loss or RTP time-frames:** Partially reported. RTP *M* = 4.8 days. Noted that no significant differences in average RTP time-frames across elite, junior-elite, and community-level competitions, however details of RTP time-frames specific to each level-of-play were NR. **Sample: Total number of players**: 1015. **Total number of injured players:** 78. **Elite-senior player hours[c]:** 20571.43. **Elite-junior player hours[c]:** 4615.38. **Community-level player hours[c]:** 3125. **Total injuries:** NA; 88 concussions. **Total injury incidence rate:** NA. **Concussion incidence: Elite-senior players:** 72 concussions, 3.5 per 1000 player-hours (95% CI, 2.74-4.38). **Elite-junior players:** 6 concussions, 1.3 per 1000 player hours (95% CI, 0.53-2.70). **Community-level players:** 10 concussions, 3.2 per 1000 player hours (95% CI, 1.63-5.70). **Concussion ranking among other injuries:** NA; only focused on concussion.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[54] Fortington, Twomey & Finch (2015) *Mechanisms of injury and management*	Secondary analysis of prospectively collected injury data from a cluster RCT.	**Sex:** Male. **Age:** 18 and over. 1564 players aged 18 and over. Followed for one playing season (2007 or 2008).18 clubs across two states. 26 weeks (pre-season and regular season) and 2 training sessions/week.
Aims/Purpose: To describe the mechanisms and follow up care of concussion injuries sustained in adult males in community Australian football to identify target areas for prevention and management. **Level of play:** Community; adults. Followed for one playing season (2007 or 2008).18 clubs across two states. 26 weeks (pre-season and regular season) and 2 training sessions/week. **Injury definition:** *An injury was defined as something that caused a player to seek medical attention (on or off the field) or to leave the field of play*. Medical staff diagnosed a concussion based on symptoms reported. **Possible-time loss.** **Recorded (Y/N): Mechanism of concussive injury:** Y; 33 concussion related to body contact with other players, including 13 from collisions with another player or umpire; 7 from being struck or hit; and 13 resulted from a tackle. One concussion occurred when a player fell on his mark landing a mark. 23 (68%) occurred within game rules, 11 (32%) occurred either outside game rules or the circumstances were unclear**. Concussion specific time-loss or RTP time-frames:** Partially reported; 88 % of players left the field immediately following concussion; 47 % later returned to play in the same game. RTP details for players who did not return on the day of injury NR. All concussions occurred during games. **Sample: Total number of players**:1564. **Total number of injured players:** 132 with HNF injuries. **Total participation hours (game and training)[c]:** 68,095,24. **Total game hours[c]:** 28163.27. **Total injuries:** 143 HNF injuries; 34 concussions. **HNF incidence rate:** 2.1 per 1000 game/training hours (95% CI, 1.78-2.47); 4.9 per 1000 game hours (95% CI, 4.13-5.77). **Concussion incidence**: 0.5 per 1000 game and training hours (95% CI, 0.35-0.70); 1.21 per 1000 game hours (95% CI, 0.85-1.67). **Concussion ranking among other injuries:** NA; only focused on concussion.		
Reference	**Study design**	**Sample: Sex. Age (range, mean, SD [years])**
[55] Makdissi & Davis (2016) *Video analysis*	Prospective cohort study	**Sex:** Male. **Age:** NR. **Concussed group:** 82 players; *M* = 24.3yrs; *SD* = 3.1

		Overall AFL cohort: 764 players; *M* = 23.1yrs; *SD* = 0.7.
Aims/Purpose: To assess the relationship between various player and game factors and risk of concussion; and to assess the reliability of video analysis for mechanistic assessment of concussion in Australian football. **Level of play:** AFL. 2011 season (22 regular rounds and 4 rounds of finals) **Concussion definition:** *All impacts and collisions potentially resulting in a concussion were recorded. Inclusion was based on factors such as the force or site of impact (e.g., high contact) and/or the immediate result of the impact (e.g., penalty for high contact, the player is slow to get up and/or taken from the ground for assessment, etc.).* All cases sent to team doctors for clinical confirmation. **Possible-time-loss.** **Recorded (Y/N): Mechanism of concussive injury:** Y. **Concussion specific time-loss or RTP time-frames:** N. **Sample: Total number of players**: 764; concussions identified from 194 games. **Total number of injured players:** 82 (assumed no repeat concussions as NR). **Player hours**[c]: 9425.29. **Total injuries:** NA; 82 concussions **Total injury incidence rate:** NA. **Concussion incidence**: 8.7 per 1000 match hours regardless of matches missed (CI, 6.96-10.74). **Concussion ranking among other injuries:** NA; only focused on concussion.		

Note. Unless RTP details were provided for each concussion, UD if time-loss occurred and have to assume time-loss involving missed matches/training and restricted participation was possible. All Confidence Intervals were estimated using the exact Mid-P method [58]. [a]Concussion/injury incidence calculated $\left(\frac{Number\ of\ concussions\ or\ injuries}{Number\ of\ player\ hours}\right) \times 1000$. [b]Player hours calculated; $\left(\frac{Number\ of\ concussions\ or\ injuries}{IConcussion\ or\ njury\ incidence}\right) \times 1000$ [c]: Not reported that participants were male, but presumed to be based on league/level-of-play details provided. **AF:** Australian Football**. AFL:** Australian Football league. **CI:** Confidence Interval. **H/N/O:** Head/neck/orofacial. **IQR:** Interquartile range. **LOC:** Loss of consciousness. **M:** Mean. **N:** No. **NR:** Not reported. **PAFIX:** Preventing Australian Football Injuries through eXercise. **Qs:** Quarters. **RCT:** Randomised control trial. **RTP:** Return-to-play. **SD:** Standard deviation. **U:** Under. **UD:** Unable to determine. **VAFA:** Victorian Amateur Football Association. **VFL:** Victorian Football League. **Y:** Yes.

Supplementary Table 4 Summary of data from Australian Football League Injury Reports from 1992 to 2005

Season; Number of clubs that participated	Concussion prevalence: matches missed per club per season (time-loss)	Concussion incidence: new concussions per club per season (time-loss)	Approximate concussion incidence: per 1000 player hours of match exposure (time-loss)[a]	Concussion recurrence rate: recurrent concussions as a percentage of new injuries	Concussion severity: average matches missed per new concussion	Concussion incidence: per 1000 players hours by first drop of Penetrometer[b]	Concussion prevalence by player age (years)
1992; 12	2.0 [4]	1.3 [4]	1.08	11% [4]	1.6 [4]	–	–
1993*[c]; 14	1.3 [4]	0.9 [4]	0.75	0% [4]	1.4 [4]	–	–
1994; 15	0.9 [4]	0.8 [4]	0.67	0% [4]	1.1 [4]	–	–
1995; 15	0.8 [4]	0.8 [5][d]; 0.9 [4][d]	0.75	0% [4]	0.9 [4][d] 1.0 [5][d]	–	–
1996; 16	1.3 [4]	0.9 [4]	0.75	0% [4]	1.4 [4]	–	–
1997; 16	0.7 [4]	0.6 [4]	0.50	0% [4]	1.1 [4]	–	–
1998; 16	0.7 [4]	0.7 [4]	0.58	0% [4]	1.0 [4]	–	–
1999; 16	0.5 [4]	0.5 [4]	0.42	0% [4]	1.1 [4]	–	–
2000; 16	0.7 [4]	0.6 [4]	0.50	0% [4]	1.1 [4]	–	–
2001; 16	1.3 [4]	0.7 [4]	0.58	0% [4]	1.8 [4]	**H:**0.8; **M:** 0.8; **S:** 0.7 [4][e]	**<21:** 1.1; **21-23:** 0.9; **24-26** :0.9; **27-29**: 0.8; **30+:**1.5 [4]
2002; 16	2.0 [5]	0.7 [5]	0.58	–	3.1 [5]	**H:**0.8; **M:** 0.6; **S:** 0.6 [5]	**<21:** 1.1; **21-23:** 0.9; **24-26** :0.9; **27-29**: 0.8; **30+:**1.5 [5]
2003; 16	0.6 [6]	0.3 [6]	0.25	–	–	–	–
2004; 16	0.3 [7]	0.3 [7]	0.25	–	–	–	–
2005; 16	0.8 [8][d], 0.9 [9-15][d]	0.7 [8]	0.58	–	–	–	–

Note: AFL club averages for injury statistics are scaled to 40 players over 22 matches. – No data available. Data from 1992-2000 was retrieved from the AFL-IRs from 2001-2016. [a] Incidence calculated based on conversion equation provided in the AFL-IR for season 2012 [15] $(\frac{concussion\ incidence}{1200}) \times 1000$. [b]Penetrometer: instrument that measures ground hardness- H: Harder (2.5 or less); M: (2.6-3.0); Softer (3.1 or greater). [c]20 matches not 22 [d]In all instances where different values are reported across AFL-IRs, all references for the value(s) are included. [e]Signficantly more injuries on harder ground. Long-term injury trends in concussion incidence reported: 1992-1996: 1; 1997-2001:0.6; 2002-2006:0.5; trend in incidence = -0.05; r value = -0.78; conclusion: fewer concussions over time [9].

Supplementary Table 5. Summary of data from Australian Football League Injury Reports from 2006 to 2012

Season; Number of clubs that participated	**Concussion prevalence: matches missed per club per season**	**Concussion incidence: new concussions per club per season**	**Approximate[a] concussion incidence: per 1000 player hours of match exposure[b]**	**Average concussion incidence: per 1000 player hours (diagnosed concussions regardless of matches missed)**	**Average concussion incidence per 1000 player hours (diagnosed concussions regardless of matches missed): 95% CI**	**Average concussion incidence: per club per season (diagnosed concussions regardless of matches missed)**	**Concussion prevalence by player age (years)**
2006; 16	0.3 [9]	0.3 [9]	0.25	–	–	–	–
2007; 16	0.3 [10]	0.3 [10]	0.25	–	–	–	–
2008; 16	0.5 [11]	0.3 [6,11][c]; 0.4 [12-15, 17-19][c]	0.25	–	–	–	–
2009; 16	0.7 [12]	0.5 [12]	0.42	–	–	–	**2005-2009 First year player:** 0.9; **Non-first year player:** 0.5; **<21:** 0.6; **21-23:** 0.6; **24-26** :0.6; **27-29**: 0.2; **30+:**0.4 [12]
2010; 16	0.8 [13]	0.5 [13]	0.42	–	–	–	–
2011; 17	2.2 [14]	1.1 [14]	0.92	8.0 [19]	6.3-9.9 [19]	7.7 [19]	–
2012; 18	1.6 [15]	1.0 [15]	0.83	9.4 [19]	7.3-12.0 [19]	9.1 [19]	**1992-1998 ≤ 21:** 1.1; **22-25:**1.1; **26+:** 0.7 [15] **1999-2005 ≤ 21:** 0.8; **22-25:** 0.5; **26+:** 1.5 [15] **2006-2012: ≤ 21:** 0.8; **22-25:** 1.0; **26+:** 1.1 [15]

Note: AFL club averages for injury statistics are scaled to 40 players over 22 matches. – No data available. [a]Terminology from AFL-IR maintained. [b]Incidence calculated based on conversion equation provided in the AFL-IR for season 2012 [15] $(\frac{concussion\ incidence}{1200}) \times 1000$. [c]In all instances where different values are reported across AFL-IRs, all references for the value(s) are included.

Supplementary Table 6. Summary of data from Australian Football League Injury Reports from 2013 to 2016

Season; Number of clubs that participated	**Concussion prevalence: matches missed per club per season**	**Concussion incidence: new concussions per club per season**	**Approximate[a] concussion incidence: per 1000 player hours of match exposure[b]**	**Average concussion incidence: per 1000 player hours (diagnosed concussions regardless of matches missed)**	**Average concussion incidence: per 1000 player hours (diagnosed concussions regardless of matches missed): 95% CI**	**Average concussion incidence: per club per season (diagnosed concussions regardless of matches missed)**	**Injury Incidence Breakdown- Match/Training/ Other (AFL v State League**	**Injury Prevalence Breakdown- Match/Training/ Other (AFL v State League**
2013; 18	1.3 [16]	1.0 [16]	0.83	6.5 [19]	4.9-8.2 [19]	6.3 [19]	–	–
2014; 18	1.6 [17]	1.3 [17]	1.08	5.9 [19]	4.4-7.6 [19]	5.6 [19]	–	–
2015; 18	4.2 [18]	1.5 [18]	1.25	6.0 [19]	4.4-7.6 [19]	5.8 [19]	–	–
2016; 18	5.6 [19]	2.3 [19]	1.92	6.3 [19]	4.5-8.1 [19]	6.2 [19]	**AFL injuries [19]** **Match:** 49% **Training:** 6% **Other: 0%** **State League injuries** **Match:** 41% **Training:** 4% **Other:** 0%	**AFL injuries [19]** **Match:** 36% **Training:** 9% **Other:** 0% **State League injuries** **Match:** 48% **Training:** 5% **Other:** 2%

Note: AFL club averages for injury statistics are scaled to 40 players over 22 matches. – No data available. [a]Terminology from AFL-IR maintained. [b]Incidence calculated based on conversion equation provided in the AFL-IR for season 2012 [15] $(\frac{concussion\ incidence}{1200}) \times 1000$.

Supplementary Table 7 Summary of Empirical Studies Focused on Exposure to Head-Impacts in Australian Football

Reference	Study design	Sample
[21] Wilmott, McIntosh, Howard, Mitra, Dimech-Betancourt, Donovan, & Rosenfeld (2017)	Prospective cohort study	34 males (*M* = 25.97, *SD* = 4.10); self-reported previous concussions (*M* = 2.57, *SD* = 1.96). 19 females (*M* = 27.32, *SD* = 4.40); self-reported previous concussions (*M* = 2.50, *SD* = 1.72). 97 players consented. 70% response rate (first reduced to 68 players due to absence at mid-week training or weekend games; a further 11 players did not record HEA, and values from 4 male players were considered extreme, leaving a final sample of 53 players).
Aims/Purpose: To assess in a cohort of amateur Australian female football players the following as they relate to game exposures: (i) SCAT3 change scores from baseline — post-game, (ii) frequency and magnitude of HAEs as measured by the X2 Patch and system, and (iii) associations between HAE exposures and SCAT3 changes. **Level of play:** Amateur (seniors and reserves). 2 clubs: males (Division 2, VFA); females (Division 1, VWFL). 2015 season. **Concussion definition (note if time-loss; possible time-loss; non-time-loss) and diagnosis (by whom):** NA. **Key outcome measures:** SCAT3 scores (baseline and post-game); frequency and magnitude of HEA; association between HEA and SCAT3 changes. **Concussion incidence rate:** No concussions reported to occur. **Findings:** Baseline SCAT was administered once within 10mins to 1-hour post-completion of a mid-week minimal contract training session. Post-game SCAT was administered once within 10mins to 1-hour post-game. The median time between baseline and post-game SCAT assessments was 4 days (range 2-44 days). No player was diagnosed with a concussion. 1394 HEA > 10g were recorded. 24 players recorded 45 HEA that were > 30g, with a median PLA of 43.2 (IQR = 33.7-51.5). Through video verification, each of these 45 HEAs were reported to have resulted from *definite* or *likely* direct head-impact. These No significant differences found in median HEA PLA between males and females ($p = 0.55$). Males recorded significantly more HEA than females ($p = 0.03$). Post-game symptom severity ($p<0.001$) and number of symptoms ($p = 0.004$) were significantly greater than at baseline. Scores on a measure of concentration significantly improved post-game compared with baseline. Neither the number of HEA or median PLA were significantly associated with SCAT3 change scores (from baseline to post-game) for either gender. Players reported average of 2.47 symptoms (*SD* = 3.40) at baseline included fatigue (49%), trouble falling asleep (17%), difficulty concentrating (17%), and neck pain (17%). Players reported an average of 3.55 symptoms (*SD* = 4.13) post-game, including fatigue (66%), feeling slowed down (34%), headaches (25%), and drowsiness (23%).		
Reference	**Study design**	**Sample**
[56] King, Hecimovich, Clark & Gissane (2017)	Prospective observational cohort study	23 male players from one WAFL club. *M* = 21 years. *SD* = 2.4yrs. 7 forwards, 11 midfielders and 5 defenders.
Aims/Purpose: To investigate the head impact acceleration characteristics with the use of wireless head impact sensors during 12 matches in adult sub-elite level ARF players. **Level of play:** WAFL. Amateur/sub-elite (seniors). 2015; 12 matches. **Concussion definition (note if time-loss; possible time-loss; non-time-loss) and diagnosis (by whom):** NA. *The biomechanical measures of head impact severity consisted of impact duration (m·s), linear acceleration (g), and rotational head acceleration (rad/s2). Head impacts were assessed by injury tolerance level for a concussing using previously published injury tolerance levels for linear and rotational acceleration.* Players at risk of concussion were identified using risk equations to analyse impact data. **Key outcome measures:** Frequency, magnitude, distribution, and risk weighted exposure of head-impacts.		

Concussion incidence rate: NR.
Findings: 4903 impacts recorded, with an average of 213 ± 315 impacts per-player, and 29 ± 37 impacts per player per-match. Location of impact included back of the head (50%), side (34%) and top (2%). Players were divided into one of three groups according to age/height/body mass distribution (lower/middle/upper) to further assess impact data. Midfielders sustained significantly more impacts (261) per player per match (36, 49) than forwards ($p < 0.0001$) and defenders ($p < 0.0001$). Significantly higher median resultant linear accelerations occurred to the top of the head, than impacts to the side ($p < 0.0001$) and back of the head ($p < 0.0001$). Significantly more total impacts (2466) were recorded for the back of the head, than the front, side, and top. Compared with midfielders ($p = 0.0009$) and forwards ($p = 0.0461$), defenders recorded significantly more impacts above the severe rotational acceleration threshold.

Note: **AFL:** Australian Football league. **HAE:** Head acceleration event. **IQR:** Interquartile range. **M:** Mean. **NA:** Not applicable**. NR:** Not reported. **PLA:** Peak linear acceleration. **SCAT3:** Sport Concussion Assessment Tool 3. **SD:** Standard deviation. **VFA:** Victorian Football Association. **VWFL**: Victorian Women's Football League. **WAFL:** West Australian Football League.