

Incidence of Concussion and Head Impacts in Australian Elite-Level Male and Female Cricketers After Head Impact Protocol Modifications

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Background: Concussion in sport is a topic of growing interest in Australia and worldwide. To date, relatively few studies have examined the true incidence of concussion in cricket.

Hypothesis: Concussion in cricket is more common than current literature suggests.

Study Design: Descriptive epidemiology study.

Level of Evidence: Level 4.

Methods: This is a prospective registry and subsequent analysis of head impacts and concussions in elite-level male and female cricketers in Australia over 2 seasons (2015-2016 and 2016-2017). A total of 172 male and 106 female domestic and international players in 2015-2016 and 179 males and 98 females in 2016-2017 were included.

Results: There were 92 head impacts (29 concussions) in men's matches and 15 head impacts (8 concussions) in women's matches. Match incidence rates per 1000 player days were 7.2 head impacts (2.3 concussions) in elite male cricket and 3.7 head impacts (2.0 concussions) in elite female cricket. This equates to a head impact every 2000 balls and concussion every 9000 balls in male domestic cricket. Concussion rates per 1000 player-match hours were 0.4 for elite males and 0.5 for elite females; 53% of head impacts in females were diagnosed as concussions compared with 32% in males, and 83% of concussions resulted in missing no more than 1 game.

Conclusion: The rate of concussion in cricket is higher than previously appreciated; however, the majority of patients recovered quickly, and players generally did not miss much playing time as a result. The institution of concussion policies after head impact, including player substitution, appears to have had an effect on increasing reporting of symptoms, resulting in an increase in diagnosis of concussion.

Clinical Relevance: Concussion in cricket is not as infrequent as previously assumed. Ongoing review of the rules and regulations is required to ensure that protection of player welfare lies in parallel with other sporting codes.

Keywords: concussion; cricket; trauma; neurology; sports medicine

Concussion has been an increasing concern in all professional and elite sports where head impacts occur,¹² particularly since the emergence of research suggesting that there may be long-term neurological and psychological consequences from concussion.¹¹ In 2014, Cricket Australia first implemented a concussion policy that included a head impact register and process for formal concussion testing,

including using the Sports Concussion Assessment Tool (SCAT3)⁴ and CogSport^{8,10} program. Furthermore, a decision was made to have all head impacts systematically assessed for concussion, irrespective of whether concussion was suspected. There were also concussion-related changes to the playing conditions in Cricket Australia. A change was implemented during the 2015-2016 cricket season at the domestic level

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allowing umpires to compulsorily remove players from the field with suspected concussion where instructed by medical staff. During the 2016-2017 cricket season, a concussion substitute was introduced for some domestic matches (all matches except first-class matches). Prior to this season, concussion substitutes were not permitted in any cricket matches, in accordance with cricket regulations.

Traditionally, the rate of concussion in cricket has been considered low. In the official injury survey, in the decade up until 2013-2014, there was an average of only 1 recorded concussion per season (year) in elite Australian men's cricket.¹⁵ Other sports have reported substantially increased rates of concussion in recent seasons.^{3,5,12} There were various possible explanations for this, most relating to the increased global awareness of concussion in sport and possibly the subsequent lowering of thresholds for clinical suspicion. Most sports have since implemented strict concussion policies and trained medical staff to detect concussion.¹⁹ Traditionally, the literature on cricket has used the definition of concussion as "an injury leading to missed playing time (that is, a player be unavailable for a match or being unable to bat or bowl during a match)."¹⁶ This definition has been expanded in this study to encompass all injuries regardless of impact on playing time, with the aim of capturing all concussions regardless of duration and severity. Finally, cricket is the only team sport where substitute players are not permitted for injured players¹⁴ other than for fielding. In practice, this rule creates a disadvantage for a team that removes a player from the field when injured, and makes the decision of medical staff to remove players from the field difficult.

The objective of this study was to report the incidence of both concussion and head impacts at the elite level in cricket over 2 consecutive seasons (2015-2016 and 2016-2017). This included all head impacts and concussions that required medical attention irrespective of whether the athlete continued playing or the impact resulted in a "time loss injury."¹⁷ The hypothesis was that increased focus on testing of players who sustain a head impact and using a definition for injury that captures all concussions, irrespective of whether there was missed playing time due to the injury, would result in an increase in diagnosis of concussion. We expected that cricket would still have a lower rate of concussion compared with many other elite sports.

METHODS

This research was approved by the Cricket Australia Research Committee after institutional approval and was conducted in accordance with the National Statement on Ethical Conduct in Human Research (2007).¹³

A prospective registry of head impacts and concussions was kept by the authors that included (1) head impact forms recorded by medical staff after every impact regardless of perceived severity on Cricket Australia's online medical recording platform (the Athlete Management System [AMS]) or completed as hard copies; (2) postimpact, concussion-specific

neurological tests (SCAT3 and CogSport) of Cricket Australia players; and (3) any additional formal or informal notification of a head impact to any of the 3 primary study authors.

Inclusion criteria consisted of match-only head impacts and concussions of elite-level male and female players competing in Cricket Australia-sanctioned international or domestic matches (see Table A1 in the Appendix, available in the online version of this article). A head impact was included on the register if a player was struck in the head or neck by a ball or during a collision with another player, a fixture, or the ground. As part of the Cricket Australia Head Trauma and Concussion Policy, all head impacts were assessed by the highest qualified medical person in attendance at the match (see Table A1 in the Appendix, available online). All impacts to batsmen struck in the helmet by a fast-bowler were reviewed on-field either immediately or at the end of the over, while slower bowlers or fielding impacts were either assessed on-field or during the next play break, at the discretion of the medical staff. On-field review included use of the Maddocks Questions^{7,18} and a brief clinical assessment to determine whether removal of the athlete from play for further review was required. Category 1 immediate signs listed in the policy require immediate and permanent removal from play, and these include loss of consciousness, confusion/disorientation, balance impairment, and tonic posturing/fitting. Category 2 clinical signs that mandate on-field assessment also include a controlled fall to the ground, stumbling or staggering, "walking away" from their position, and disengaging with the game. All diagnoses were confirmed by a same-day clinical review and neurocognitive (SCAT3 and CogSport) testing by a qualified medical officer associated with the team. All head impacts were recorded on the day of incident and entered into the AMS. After entry into the AMS, an alert was automatically sent to the researchers to ensure the data were collated in a systematic manner. Each impact was documented in relation to the location of impact, position of player, presence of a helmet, immediate clinical signs, and postimpact neurological assessment (either immediate if the player was removed or end of the day if the player remained in the game). Our aim was to capture all head impacts, regardless of perceived severity. Given the nature of cricket, we believe the vast majority were indeed captured, as play postimpact is often halted. This is in contrast to other sporting codes, where active match play continues despite head impacts and on-field assessments.

The diagnosis of concussion was in accordance with the Berlin Concussion Consensus¹² and incorporated (1) occurrence of a head, helmet, or neck impact (by a ball, bat, fixture, or collision with another person or the ground) AND (2) the doctor's establishing that symptoms were a result of the impact AND/OR signs of dysfunction subsequent to the impact (eg, loss of consciousness, amnesia, stumbling, vomiting, seizures, poor balance, inability to quickly resume playing) AND/OR abnormality on formal neurocognitive testing (SCAT3 or CogSport).

Ultimately, the diagnosis of concussion in cricket, as is the case in all sports, remains a clinical judgement of the attending

Table 1. Comparison between rates (per 1000 player days) for the 2015-2016 and 2016-2017 seasons in Australian domestic cricket

Match Type	2015-2016		2016-2017	
	Concussion Incidence	Head Impact Incidence	Concussion Incidence	Head Impact Incidence
Sheffield Shield	2	7.2	2.8	11.7
Futures League	0.5	1.6	4.9	5.5
Matador Cup	0	4	4	11.9
BBL	0	5.2	2.6	11.7
WNCL	6.2	6.2	0	2.1
WBBL	0.8	3.1	3.1	4.6

BBL, Big Bash League; WBBL, Women's Big Bash League; WNCL, Women's National Cricket League.

doctor, with the components listed serving as adjuncts to support the diagnosis. The Cricket Australia Head Injury and Concussion Policy outlines that all head impacts are monitored and assessed for at least 24 hours postincident, including progressive symptom review and 24-hour follow-up computerized neurocognitive testing (CogSport).^{1,2,6} Therefore, it was possible that a concussion diagnosis could be made at any of the following time points: soon after the head impact (immediate diagnosis), later in the game, or after the game (delayed diagnosis). The Cricket Australia Head Injury and Concussion Policy return-to-play criteria mandates that return to physical activity must not occur for at least 24 hours after concussion diagnosis, and our return-to-play process follows a staged progression similar to that described by the Berlin Concussion Consensus Statement.¹² Neurocognitive testing is repeated at 24 hours, and if deficits persist, it must be repeated until baseline is reached (minimum 24 hours between testing). Athletes must be asymptomatic with baseline neurocognitive testing and no clinical worsening with exercise provocation before they can return to play.

The primary units of incidence calculated for head impacts and concussions, respectively, were head impacts/concussions per 1000 player days as per the international cricket consensus definitions.¹⁶ A limited 50- or 20-over match (where both teams were part of the study) constituted 22 player days (11 for each team). A 2-inning match played over 4 days, for example, constituted 88 player days (44 player days for each team).

A secondary measure of incidence was the number of head impacts and concussions, respectively, per ball bowled. Because of the very small risk of head impact or concussion, rates were expressed in terms of the number of balls bowled to generate 1 concussion. Where a result was expressed as 1 concussion per 5000 balls, for example, this represents 1 concussion for *all* players on the field in every 5000 balls, bearing in mind that the majority (but not all) of this risk is borne by the striker (batter facing the bowling).

For comparison with other sports, a third incidence measure was calculated using concussions per 1000 player (match) hours. The 3 formats of cricket were assumed to have a duration of 3 hours (T20), 6 hours (first class), and 6.5 hours (50-overs).

RESULTS

There were 172 male and 106 female domestic and international players in the 2015-2016 season, and 179 male and 98 females in 2016-2017 season (see Table A2 in the Appendix, available online).

Over the 2 seasons, there were 92 head impacts that resulted in 29 concussions in all men's teams (on 1178 team days of play) and 15 head impacts that resulted in 8 concussions in women's matches (on 367 team days of play). The match incidence rates were 7.2 head impacts (2.3 concussions) per 1000 player days in elite male cricket and 3.7 head impacts (2.0 concussions) per 1000 player days in elite female cricket. For perspective, a rate of 7.2 head impacts and 2.3 concussions in 1000 player days in elite men's cricket means that 1 of the 11 players on each team can expect a head impact every 12 days of play, and every 36 days of match play, 1 of the players in the team will suffer a concussion.

There were apparent increases in the concussion rates in men's cricket in 2016-2017 compared with 2015-2016, particularly in the non-first-class formats. However, in women's cricket, the rates did not substantially change (Table 1).

Throughout the 62 games of the Sheffield Shield over the 2 seasons analyzed, there were 110,000 balls bowled, of which 47 led to head impacts (approximately 1 in every 2000 balls) and 12 led to concussions (1 in every 9000 balls) (see Table A3 in the Appendix, available online). The striker (batter facing the bowling) generally bore the majority of this risk, but not all (Table 2).

Table 2. Mechanism of all head impacts, 2015-2016 and 2016-2017

Primary Role at Time of Impact	Mechanism	Cases	Percentage of All Head Impact Cases
Batting	Direct hit from ball bowled by fast bowler, after bouncing	72	67
	Hit when facing spin bowling	4	4
	Hit by throw when running	3	3
	Hit as nonstriker by shot of teammate	1	1
	Total		75
Bowling	Bowler hit directly by batsman's shot	1	1
	Total		1
Wicketkeeping	Wicketkeeper hit by ball	4	4
	Wicketkeeper hit by bat	2	2
	Wicketkeeper hit by throw	1	1
	Total		7
Fielding	Close-in fielder hit by ball	9	8
	Collision with fence	1	1
	Colliding with another fielder	3	2
	Head hitting ground	6	6
	Total		17

Batters (male and female) sustained 75% of head (helmet) impacts. The most common batting mechanism was being struck by a ball being bowled by a fast bowler (67% of all impacts), although this mechanism did not occur in women's cricket, likely as result of comparatively slower bowling. Impacts as a result of spin bowlers only accounted for 4% of all head impacts, none of which led to concussion. Close-in fielders (8%), outfielders (8%), wicketkeepers (7%), and bowlers (1%) all sustained head impacts (Table 2). In women's matches, 53% of head impacts resulted in concussions, compared with 32% of head impacts in men's matches.

The majority of concussions were "delayed concussions." Of the 37 concussions, 11 (30%) players were removed immediately after impact (Table 3). A further 17 (46%) were diagnosed with concussion and removed at a later stage in the same game, and 9 (24%) players were diagnosed after the game had finished (Tables 3 and 4). On 7 occasions in the 2016-2017 season, a concussion substitute was activated (1 Matador Cup, 2 Women's Big Bash League, 1 Big Bash League, and 4 in Futures League games).

In players sustaining a concussion, there were no subsequent games missed on 21 occasions, 1 missed game on 10 occasions, 2 missed games on 3 occasions, and more than 2 missed games on 3 occasions.

DISCUSSION

The rate of concussions (2.3 and 2.0 concussions per 1000 player days in elite men's and women's cricket, respectively, and 1 in 9000 and 1 in 6000 balls, respectively) was higher than previous studies in cricket.¹⁷ This equates to 0.4 and 0.5 concussions per 1000 player hours for male and female elite cricket, which is significantly less than the comparative rates in Australian Football, which have typically been between 3 and 10 concussions per 1000 player hours.⁹

The institution of a policy with compulsory concussion testing after all head impacts appears to have had a major effect on capturing the diagnosis of concussion, particularly in the 2016-2017 season. Additionally, the availability of a concussion substitute in some match types in the 2016-2017 season may have also contributed to the increase in self-reporting of symptoms, aiding diagnosis.

Almost one-third (30%) of concussion diagnoses were made immediately after head impact and the athlete was removed from the game, while the remaining concussions were classified as delayed concussions, occurring later in the same match or after the match. We believe our high rate of delayed

Table 3. Summary of on-field assessment of head impacts^a

	Immediate Removal	Continued to Play	Total
Concussion	11	26	37
Impact only	1	69	70
Total	12	95	107

^aSensitivity, 30%; specificity, 99%; positive predictive value, 92%; negative predictive value, 73%.

Table 4. Summary of dressing/medical room assessment of head impacts^a

	Held Out of Game	Allowed to Finish Game	Total
Concussion	27	10	37
Impact only	0	70	70
Total	27	80	107

^aSensitivity, 73%; specificity, 100%; positive predictive value, 100%; negative predictive value, 88%.

concussions stems from the multiday nature of the sport and our tight regulations around continued monitoring after impact regardless of initial clinical concerns. Our policy has a strict immediate/permanent removal of play for any players with clear signs and symptoms of concussion immediately postimpact. It is the impacts without these immediate features that are most difficult to manage, and the threshold for removal of play remains a tough clinical decision for medical staff. Whether the delayed cohort is a result of players withholding symptoms to remain in play or a true presentation of delayed onset concussion is unfortunately near impossible to determine. Some of the match types in cricket (eg, first class/test matches) are multiday games, and concussion diagnosis could have been made on subsequent days. This is a strength of the Cricket Australia Head Impact and Concussion Policy, which requires all head impacts to be monitored and assessed for concussion in the days after the incident. This may have resulted in the higher number of delayed concussions recorded in this study.

The duration of concussive syndromes was relatively mild. Of the 37 concussions, 21 players did not miss a game as a result, and a further 10 missed only 1 game. The average duration of concussion previously reported in other sports is 10 to 14 days.¹ Without a regular weekly fixture, interpretation of games missed in cricket can be misleading.

A limitation of this study is the subjectivity of diagnosis and variability in the clinical judgement. It is possible that the true incidence of concussion was underestimated or overestimated in this study. There were occasions when a player had been seen by 2 medical practitioners (on different occasions). In these situations, if 1 doctor diagnosed concussion and the other did not, we presumed the player had a concussion. Head impacts with fielders diving toward the ground have a potential to be missed, along with subtle glancing blows to the helmet if deflected from a glove or shoulder. The attending doctor may be given access to delayed video replay of each delivery, helping minimize this risk; however, this is not always available, and the use of video for concussion in cricket is still undergoing review prior to official implementation. Umpires do have the authority to cease play and request medical review of a player they believe sustained a blow to the head, however there still remains a reliance on the match-day doctor to remain vigilant in game observation. Given the nature of the sport, fortunately, most impacts result in a significant delay of game, which helps with prompt attention and assessment. Finally, our data are based on assumed match durations, which in a win-loss spectrum has a variable timeframe.

CONCLUSION

This study shows that concussion in cricket occurs at a much higher rate than previously appreciated, although the clinical course of most cases is short (only 16% of players missed 2 or more games due to concussion). A substantial minority of head impacts in elite cricket result in concussion.

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