ORIGINAL ARTICLE

Converging evidence for the under-reporting of concussions in youth ice hockey

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Background: Concussions are potentially serious injuries. The few investigations of prevalence or incidence in youth ice hockey have typically relied on prospective reports from physicians or trainers and did not survey players, despite the knowledge that many athletes do not report probable concussions.
Objective: This study sought to compare concussion rates in youth ice hockey that were estimated from a variety of reporting strategies.
Methods: Rates were calculated from British Columbia Amateur Hockey Association (BCAHA) official injury reports, from direct game observation by minor hockey volunteers (such as coaches and managers), as well as from retrospective surveys of both elite and non-elite youth players. All research was conducted within the BCAHA.
Results: Estimates from official injury reports for male players were between 0.25 and 0.61 concussions per 1000 player game hours (PGH). Concussion estimates from volunteer reports were between 4.44 and 7.94 per 1000 PGH. Player survey estimates were between 6.65 and 8.32 per 1000 PGH, and 9.72 and 24.30 per 1000 PGH for elite and non-elite male youth hockey, respectively.
Conclusion: It was found that concussions are considerably under-reported to the BCAHA by youth hockey players and team personnel.

Concussions are typically generated by rapid acceleration, deceleration, or rotation of the head, leading to compressive, tensile, and shearing forces on the brain.[1] The deleterious effects associated with the injury may include neuropsychological deficits, temporary impairments in information processing and cognition, and a variety of symptoms associated with postconcussion syndrome (PCS).[1–6] There is also emerging evidence supporting the cumulative detrimental effects of multiple concussions, the lingering of PCS for periods of a year or longer, and the risk of coma or death following concussive injuries.[1 3–5 7–10] Clearly, concussions can become serious injuries for those victims who experience severe outcomes or suffer from the effects for long durations.

The occurrence of concussion in minor (youth) ice hockey is well established and perhaps not surprising given the speeds at which players travel, the enclosed environment in which they compete, and the collisions, including body-checks, that are frequently used as an elemental tactic in game play.[11–22] Epidemiological assessment of concussion is critical to determine the need for prevention and control measures, and various professional and semiprofessional hockey leagues (such as the National Hockey League and Ontario Hockey League) now have surveillance systems in place. However, the incidence of concussion in youth hockey is not firmly established. While a small number of risk estimates have been calculated,[14 19 22] most studies are confined to reporting prevalence,[11–13 15–17 20–22] which offers some insight into the occurrence of concussion, but does not provide such a clear picture of the risk posed to exposed populations.

Of those investigations that have reported incidence, estimates are often obtained from very different data sources and based on very different methods of surveillance, making comparison difficult. Moreover, epidemiological studies of concussion in youth ice hockey typically only use prospective injury reporting by athletic trainers or sports medicine physicians to establish the frequency of injury.[11 12 14–16 19 21–24] While this is may be the preferred methodological approach for clinical diagnosis of concussions, it relies almost entirely on hockey players reporting their injuries to team personnel. In circumstances when a concussion presents with loss of consciousness, noticeable post-traumatic amnesia, or severe disorientation, this may not be an issue, but the vast majority of concussive injuries are considered mild (no loss of consciousness, or post-traumatic amnesia) and difficult to diagnose.[1 25] In these instances, players would need to recognise and report their symptoms to team personnel before the incident is going to be appropriately recognised and managed. Only a limited number of studies have incorporated player reports of concussive injuries into the prospective study design,[12 20 26 27] and the degree to which prospective studies under-report the occurrence of concussions is unknown.

Given the large numbers of North American and European youth players currently participating in ice hockey, it is important that we obtain an accurate estimate of the concussion rate so that players and parents can begin to make informed decisions about participation and administrators can be guided to control parameters that may affect this rate. In this study, we present evidence to suggest that there is considerable under-reporting of concussions in youth ice hockey and that rate estimates calculated from official injury reports data woefully underestimate the true incidence. We compared rate estimates of concussion and incidents of concern calculated from a Canadian provincial league's official injury forms, reports from minor hockey team volunteers, and retrospective surveys of youth hockey players.

MATERIALS AND METHODS

Three different strategies were used in four different projects to assess the rate of concussion in youth hockey: official

Abbreviations: AE, athlete exposures; BCAHA, British Columbia Amateur Hockey Association; PCS, postconcussion syndrome; PGH, player game hours

injury reports, direct observation, and retrospective player surveys. All data were collected from teams and games in the British Columbia Amateur Hockey Association (BCAHA), a provincial governing branch of Hockey Canada. Body checking is permitted in male hockey from 11 years of age onward. Informed written consent was obtained in all projects when there was direct contact with participants. The research ethics board of Simon Fraser University approved these projects.

Official injury reports

The BCAHA provided injury reports from the pee wee (11 and 12 years), bantam (13 and 14 years), and midget (15–17 years) age divisions for male hockey players, and also reports from female hockey divisions (12–19 years). Injury reports are filed by team personnel and collected by the BCAHA and Hockey Canada on an ongoing basis for insurance purposes and have been used for tracking injuries (see www.hockeycanada.ca/e/develop/insurance/downloads/safety_net_e.pdf). According to Hockey Canada, they are to be completed

> ''for each case where an injury is sustained by a player … at a sanctioned hockey activity.''

Official injury reports include descriptive information about the injured player (such as name and home association), the details of the event, and the nature of the injury. For the purposes of this study, copies of all forms submitted to the BCAHA during the 2003–2004 season were screened for explicit reports of concussions.

Direct observation

During the 2002–2003 hockey season, minor hockey team volunteers (coaches, managers, or safety personnel) in a district of the BCAHA were asked to record and report the details of ''head incidents of concern'' sustained by their team's players during games. A head incident of concern, or incident, was defined as a physician diagnosed concussion or an episode considered seriously indicative of a concussion based on observed signs or symptoms. Most coaches and all safety personnel have passed the Canadian Hockey Safety Program, which includes information addressing concussion symptoms and assessment. Although the signs and symptoms associated with concussion can be associated with other conditions, when presenting after rapid acceleration or deceleration of the head they are considered indicative of concussion, and diagnosis with symptoms has been an integral element of other investigations.[4 13 25 28–30]

In total, 44 team volunteers represented 44 teams and 792 players from three hockey age divisions: pee wee, bantam, and midget. Participants were phoned or e-mailed with project updates twice monthly. Reports of head incidents of concern were completed using a standardised form submitted by mail, fax, drop box, or an online web page.

Retrospective player surveys

A self reporting retrospective questionnaire was developed to gather information about the concussion histories of youth hockey players. Participants were asked to report if they had ever suffered a significant hockey induced hit to the head that presented signs and symptoms of concussion. Participants who reported sustaining such an injury (a head incident of concern) then reported the details of the event and the associated symptoms. Players could report any head injuries sustained in their hockey careers, but only injuries incurred in the current or prior season were included in the analysis to improve the accuracy of the injury recall.[31]

Elite players

Participants in 12 BCAHA elite hockey tournaments occurring between 2001 and 2003 (three tournaments each year) completed the questionnaire. The two annual male tournaments included players aged in the under-16 and under-17 year age groups, respectively, while the female annual tournament included players <18 years. Histories of players who participated in two or more years of competition and who reported suffering a concussion were reviewed to ensure each incident was counted only once.

Non-elite (recreational) players

Non-elite hockey players completed a similar self report retrospective concussion history questionnaire. Testing included players aged 11–17 years (pee wee, bantam, and midget) from a single BCAHA minor hockey association in January 2004.

Calculation of incidence

Recent sport surveillance literature has expressed incidence in terms of injuries per 1000 athlete exposures (AE) and injuries per 1000 player game hours (PGH), so we present both calculations here. Previous research has indicated the vast majority of concussions and other hockey induced injuries occur during games.[17 26 29 32–34] For this reason, all concussions or incidents were assumed to have transpired during games and the number of concussions that occurred during practices was assumed to be negligible.

Because time at risk (AE and PGH) for individual players was not tracked during these investigations, exact player exposure during games could not be calculated. Thus, player game time at risk was estimated for an 18 member team playing an entire game at full strength (no penalties) with five skaters and a goalie on the ice. A typical BCAHA sanctioned game is 45 minutes of stopped time played within 1–1¼ hours. PGH at risk is equal to six skaters/team × 0.75 hours per game, or 4.50 hours/game/team. Each player on an 18 member team is therefore at risk for 0.25 hours per game. Similar methods have been used in prior investigations.[16 19 25 26]

Athlete exposures

For the purposes of this investigation, an AE was considered participation in a game where the player is exposed to the possibility of injury. The incidence of concussions or incidents of concern per 1000 AE was calculated as the number of concussions reported during the observation period/the total number of AE among all players during observation period × 1000 AE. The number of games (AE) that occurred during the observation period of each study cohort varied depending on the age and skill groups involved, so minimum and maximum estimates of the total number of games played during each study period were determined based on a sample of schedules from each cohort's category of competition. The minimum total AE among all players during each observation period was calculated as number of players × minimum number of games for a specific cohort, and maximum total AE among all players during each observation period was number of players × maximum number of games for a specific cohort. Minimum and maximum estimates of incidence were then calculated using the maximum and minimum total AE, respectively.

Player game hours

The incidence of concussion or incidents of concern per 1000 PGH was calculated as (number of concussions reported during observation period/total PGH at risk during observation period) × 1000 PGH. Minimum and maximum total PGH at risk during each observation period were calculated

as minimum total games played by all players (AE) × 0.25 hours/player/game and maximum total games played by all players (AE) × 0.25 hours/player/game, respectively. Minimum and maximum estimates of incidence were then calculated using the maximum and minimum total PGH at risk, respectively.

RESULTS

The details and results of the investigations as well as estimates of the rates of concussions or incidents of concern in terms of both AE and PGH are presented in table 1. The duration of observation for each project is reported as the time period. In considering the retrospective survey results, between 2001 and 2004, 178 (of 497) male and 112 (of 326) female elite players reported sustaining at least one hockey induced concussion. Based on the reported age when the concussion occurred and player birth dates, 79 elite male and 69 elite female athletes reported at least one hockey induced concussion in the current or prior season. Of 107 non-elite athletes, 26 reported sustaining at least one concussion during the current or prior season.

DISCUSSION

The range of incidences per 1000 PGH calculated from each observation strategy is shown in fig 1. There are considerable differences between the incidences of concussion based on official injury reports and those calculated from the other observation strategies (>30 fold difference between official injury reports and non-elite retrospective surveys for male players). Indeed, even using very conservative estimates of the number of games in each study cohort, our data suggest considerable under-reporting of concussions to the BCAHA. A similar figure is observed if the results are calculated in units of 1000 AE.

The prevalence of self reported incidents suggests that many players (elite and non-elite alike) recognise when they have sustained a significant hit to the head that presents signs and symptoms of concussion. Unfortunately, many of these incidents do not appear to be reported (or perhaps even recognised) by team volunteers and fewer still are reported to the BCAHA. This is despite Hockey Canada's Coach and Safety Person Protocol, which recommends that all players demonstrating signs of concussion be removed from play and not permitted to return until advised by a physician (www.hockeycanada.ca/e/develop/safety/concussion.html). The under-reporting of concussions also appears to occur in female hockey.

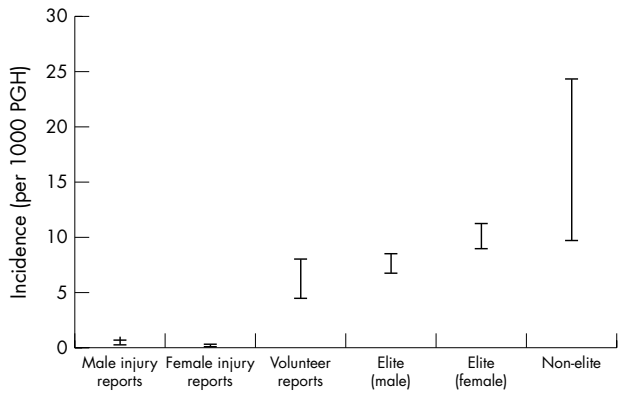

Figure 1 Range of incidence estimates per 1000 PGH across different observation strategies.

Table 2 compares median rate estimates from this study with those calculated using reported data from previous investigations of injury incidence in youth male ice hockey. With the exception of Gerberich *et al*,[13] the cited studies used a prospective surveillance system requiring injury diagnosis by an athletic trainer or a physician. Roberts *et al*[18 19] report rates similar to or exceeding those reported by the athletes in our investigation, perhaps because these studies included all injuries evaluated by a team physician or trainer, regardless of severity, and did not necessitate referral to a physician due to injury,[21 22] 24 hours' absence from participation due to injury,[21 22] or loss of consciousness or post-traumatic amnesia.[13]

The variability in estimates from this investigation and across past studies reiterates a call for standardisation of surveillance measures and methods in ice hockey.[35] Table 2 supports the notion that the surveillance methods used may dramatically influence estimates of injury and, in turn, the conclusions of an investigation. Our findings suggest that future studies must continue to make clear the possible limitations of their methods.

This study is subject to some important limitations. Firstly, it was assumed that team volunteers and players are capable of appropriately identifying the signs and symptoms consistent with a concussive injury. Although many coaches and all safety personnel have passed the Canadian Hockey Safety Program, we did not confirm if our volunteers had completed the course. Secondly, a definitive diagnosis criterion for concussions remains elusive, so we were limited to using concussion symptoms. Thirdly, selection bias may be a

Table 1 Measured parameters and minimum and maximum incidence estimates across different observation strategies

	BCAHA official injury reports		Direct observation	Retrospective survey		
Parameter	Male (PW, B, M)	Female (all levels)	Volunteer reports	Elite (male)	Elite (female)	Non-elite
Time period	1 season	1 season	3.5 months	2 seasons	2 seasons	2 Seasons
No. of players at risk	19548	5017	792	475	309	107
No. of CX or IOC*	60	7	22	79	69	26
AE						
Minimum no.	20	20	14	80	80	40
Maximum no.	50	50	25	100	100	100
Minimum incidence*	0.06	0.03	1.11	1.66	2.23	2.43
Maximum incidence*	0.15	0.07	1.98	2.08	2.79	6.07
PGH						
Minimum no.	97 740	25 085	2772	9500	6180	1070
Maximum no.	244 350	62 713	4950	11 875	7725	2675
Minimum incidence*	0.25	0.09	4.44	6.65	8.93	9.72
Maximum incidence*	0.61	0.28	7.94	8.32	11.17	24.30

PW, Pee wee; B, Bantam; M, Midget; CX, concussion; IOC, incident of concern. *Per 1000 PGH.

Table 2 Investigation of male youth ice hockey incidence and calculated estimates from the literature

Study	Period	Type	Country	Age (years)	No. of players	No of concussions	Exposure (PGH)	Incidence (/1000 PGH)
Official reports	2003–2004	Retro	Canada	12 to 17	19548	60	17 1045	0.35
Volunteer reports	2002–2003	Pro	Canada	12 to 17	792	22	3861	5.70
Elite	2001–2003	Retro	Canada	15 to 17	475	79	10 688	7.39
Non-elite	2004	Retro	Canada	11 to 17	107	26	1605	16.20
Gerberich[13]	1982–1983	Retro	USA	16.1‡	251	22	4141.5*	4.35
Roberts[19]	1993–1994	Pro	USA	12 to 13	132	2	86.4	23.15
				14 to 15	127	1	93.6	10.68
				12 to 15	163	2	108	18.52
Roberts[18]	1994	Pro	USA	<20	273	4	213.9	18.70
Smith[21]	1994–1995	Pro	USA	NR	86	1†	639‡	1.56
Stuart[22]	1993–1994	Pro	USA	16 to 21	66	0	4707	0

The first four rows of the table are from the present study. Results are calculated from: *mean number of game hours per player × number of players; †number of injuries × proportion of injuries that were concussions; ‡number of injuries ÷ incidence of injury per player game hour. ‡Median; all other numerical values in this column are range. Retro, retrospective; P, prospective; NR, not reported.

limitation in this study; team volunteers who had prior experience in dealing with concussions or had an attitudinal bias may have been more willing to volunteer for the programme or report incidents than were the general population of team volunteers. Fourthly, the questionnaire may not have captured all possible concussions; surveyed players who had unwittingly sustained a previous concussion because they were unable to recognise the associated symptoms, or who sustained a potential concussion by way of an indirect mechanism may not have answered affirmatively. We believe, however, that both these questionnaire limitations lend further evidence to support the under-reporting of concussion in youth ice hockey. It should also be noted that the use of this tool may have introduced recall bias. Finally, the means by which we calculated time at risk for each study cohort were based on educated assumptions of the number of games played and time at risk during each game. This was necessary in order to utilise several data sources in a comparison using measures consistent with the literature (AE and PGH).

It should be noted that these estimates are not intended to be conclusive measures of the rate of concussion in youth hockey, but rather to demonstrate the considerable differences in rates of concussion or incidents as calculated from reports to the hockey governing bodies, from volunteers, and by the players who suffer injuries seriously indicative of concussions. We feel they are strong evidence to indicate a considerable under-reporting of concussive injuries in youth hockey, both to the hockey governing bodies and to team personnel. In addition, we feel these results suggest studies relying exclusively on prospective injury reports by team personnel—that is, studies that do not regularly consult with players, are likely to under-report the true rate of concussion.

CONCLUSION

Based on the converging evidence cited above, the under-reporting of concussions to the hockey governing bodies, both by players and by bench staff, remains a major problem in youth hockey in British Columbia. There is no reason to believe that this is not also the case in other Canadian provinces, which operate under the same principles of Hockey Canada. The under-reporting of these injuries to the hockey governing bodies has important implications for decision makers and parents who rely on these data to make informed decisions about the risk of concussion in the game of hockey. Of particular concern to us is the under-reporting of concussions by players to team staff. Players who do not report incidents indicative of concussions and return to play while still symptomatic may be placing themselves at risk of further injury, thereby increasing the risk of the cumulative detrimental effects of multiple concussions and the risk of further injury.[7–9 36]

Hockey Canada has recently indicated a desire to expand the use of injury reports to create an injury tracking system in minor hockey (see website given above). Unless appropriate steps are taken to address the under-reporting of concussions and other injuries, results obtained from this data source may be inaccurate. We feel our findings indicate the importance of surveying athletes engaged in a prospective study of sport induced injury. Studies based solely on administrative records (such as official injury reports or hospital records) or reports from team staff (such as athletic therapists, physicians, and volunteers) may not account for all concussions.

What is already known on this topic

- Goodman *et al*[25] found 50% of junior hockey players, when surveyed retrospectively, did not report injuries they recognised as concussions during prospective investigation.
- Researchers appear to acknowledge this under-reporting, but no efforts have been made to quantify it.

What this study adds

- It is the first to demonstrate there is a substantial under-reporting of concussion at several levels within youth hockey organisations.
- It also demonstrates methods dependent on prospective player reports alone likely underestimate the true risk.

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COMMENTARY

This article helps highlight the issue of how different sources of concussion statistics can be misleading and how many of these sources can vastly underestimate the rates of concussions. In this study, when assessing concussion rates in athletes from different reporting sources, the rates varied almost 100-fold from one source to another. If we combine the findings of this study with the fact that most concussions go unrecognized and/or unreported, it is obvious that much of the published data on rates of concussions are, in reality, only a small fraction of what is actually occurring in the athletic population.

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