

Risk of Injury Associated With Body Checking Among Youth Ice Hockey Players

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ICE HOCKEY IS A POPULAR NORTH American winter sport, with more than 550 000 registered youth players in Hockey Canada and more than 340 000 registered players in the USA Hockey Association in 2008-2009.^{1,2} Despite the advantages of sport participation, there is increasing concern regarding the frequency of ice hockey injuries in youth. Canadian data suggest that hockey injuries account for 10% of all youth sport injuries.^{3,4} Body checking has been associated with 45% to 86% of injuries among youth ice hockey players.⁵⁻⁸ Recently, attention has been focused on the increased frequency of concussive head injuries in youth hockey.⁹ Concussion has been found to be the most common type of specific injury, accounting for more than 15% of all injuries in 9- to 16-year-old players.^{7,10}

Internationally, there are different regulations regarding the age at which body checking is introduced in ice hockey. In the United States, body

Context Ice hockey has one of the highest sport participation and injury rates in youth in Canada. Body checking is the predominant mechanism of injury in leagues in which it is permitted.

Objective To determine if risk of injury and concussion differ for Pee Wee (ages 11-12 years) ice hockey players in a league in which body checking is permitted (Alberta, Canada) vs a league in which body checking is not permitted (Quebec, Canada).

Design, Setting, and Participants Prospective cohort study conducted in Alberta and Quebec during the 2007-2008 Pee Wee ice hockey season. Participants (N=2154) were players from teams in the top 60% of divisions of play.

Main Outcome Measures Incidence rate ratios adjusted for cluster based on Poisson regression for game- and practice-related injury and concussion.

Results Seventy-four Pee Wee teams from Alberta (n=1108 players) and 76 Pee Wee teams from Quebec (n=1046 players) completed the study. In total, there were 241 injuries (78 concussions) reported in Alberta (85 077 exposure-hours) and 91 injuries (23 concussions) reported in Quebec (82 099 exposure-hours). For game-related injuries, the Alberta vs Quebec incidence rate ratio was 3.26 (95% confidence interval [CI], 2.31-4.60 [n=209 and n=70 for Alberta and Quebec, respectively]) for all injuries, 3.88 (95% CI, 1.91-7.89 [n=73 and n=20]) for concussion, 3.30 (95% CI, 1.77-6.17 [n=51 and n=16]) for severe injury (time loss, >7 days), and 3.61 (95% CI, 1.16-11.23 [n=14 and n=4]) for severe concussion (time loss, >10 days). The estimated absolute risk reduction (injuries per 1000 player-hours) that would be achieved if body checking were not permitted in Alberta was 2.84 (95% CI, 2.18-3.49) for all game-related injuries, 0.72 (95% CI, 0.40-1.04) for severe injuries, 1.08 (95% CI, 0.70-1.46) for concussion, and 0.20 (95% CI, 0.04-0.37) for severe concussion. There was no difference between provinces for practice-related injuries.

Conclusion Among 11- to 12-year-old ice hockey players, playing in a league in which body checking is permitted compared with playing in a league in which body checking is not permitted was associated with a 3-fold increased risk of all game-related injuries and the categories of concussion, severe injury, and severe concussion.

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checking is introduced in all leagues in the Pee Wee age group (ages 11-12 years), but leagues not permitting body checking exist through all ages up to Midget (ages 15-16 years).¹¹ In Canada, the youngest age group in which body checking is permitted is Pee Wee (ages 11-12 years).¹² In the province of Quebec, however, Bantam (ages 13-14 years) is the youngest age group in which body checking is permitted. Otherwise, in Canada, rules of play are mandated by Hockey Canada and are consistent across all provinces.¹²

The policies allowing body checking at the Pee Wee level in Alberta and the Bantam level in Quebec provided a unique opportunity to examine whether the risk of concussion and injury differs for Pee Wee ice hockey players in a league that permits body checking vs a league that does not.

METHODS

Study Objectives

The primary objectives of this study were to examine whether the risk of concussion and other injury during games and practices differs for Pee Wee ice hockey players in a league that permits body checking vs a league that does not. Secondary objectives included examining the difference between the cohorts for severe concussion (time loss, >10 days) and severe injury (time loss, >7 days). In addition, the risk associated with other previously identified risk factors were examined: year of play (ie, first or second), previous injury or concussion, player size, level of play, position of play, and attitudes toward body checking.

Sample, Design, and Data Acquisition

A prospective cohort study was conducted during 1 season of play (October 2007-March 2008). The study population was Pee Wee (ages 11-12 years) ice hockey players. Cohorts were defined by their exposure to a league with rules that permitted body checking. Inclusion criteria were the following: players aged 11 through 12 years during the season of play; male or fe-

male players; written informed consent to participate (player and one parent or guardian); players registered with Hockey Calgary, Hockey Edmonton, or Hockey Quebec; players participating in the Pee Wee age group only; players in the top 60% by level of play; agreement of the head coach to participate in the study; and agreement of a team designate (coach, safety manager, or other team parent) to collect information on individual player participation. Teams and players were excluded if they participated in a "girls-only" Pee Wee league or had sustained a previous injury or chronic illness that prevented full participation in hockey at the beginning of the 2007-2008 season.

Written informed consent was obtained from each player and parent or guardian. Approval was granted from the ethics offices at the University of Calgary, University of Alberta, McGill University, Université de Montréal, and Laval University.

A sample size of 1944 (972 from each province) was determined necessary for a minimally important incidence rate ratio (IRR) of 2 or greater based on an expected concussion rate of 1 per 1000 player-hours in the Alberta cohort, adjusting for cluster and an anticipated drop-out rate of 10% (2-sided test; $\alpha = .05$, $\beta = .20$).¹³

Definitions and Analytic Design

The injury surveillance system used in this study was based on the Canadian Intercollegiate Sport Injury Registry, which was modified and validated for use in youth ice hockey.^{4,14} Three data collection documents were used: a preseason baseline questionnaire, weekly exposure sheet, and injury report form. All forms were translated into French for Quebec players and therapists whose preferred language was French. Each team was assigned a physiotherapist, athletic therapist, or senior therapy student who attended 1 session per week for their assigned team. The team therapist was responsible for all data collection and injury assessment.

Preseason questionnaires were distributed to all consenting players. The forms were completed with parental assistance when necessary. Baseline data collected included height, weight, date of birth, previous injuries, previous concussion, years of hockey participation, and skill level. In addition, the Sport Concussion Assessment Tool¹⁵ and a body checking questionnaire¹⁶ examining attitudes toward body checking were completed at baseline.

The weekly exposure sheet was a record of the daily participation data collected by a team designate on each consenting player for all team practices and games. For teams missing occasional weeks of weekly exposure information, exposure data were imputed based on the mean game and practice hours in the weeks that the team had complete weekly exposure data. Given the consistency of ice time distribution for games and practices within a given hockey association and league, this was felt to be an appropriate estimate.

The injury report form included details related to mechanism of injury, time, date, session type, time loss, medical follow-up, and the therapist's specific injury assessment. The injury mechanism categories included body checking, other intentional player-player contact (elbowing, cross checking, slashing, tripping, roughing), incidental body contact (contact with another player that did not meet the definition of body checking or other intentional contact), environmental contact independent of contact with another player (puck, boards, net), and no contact. These previously validated mechanisms were defined a priori, and all study personnel (team designates and therapists) were educated regarding injury mechanism definitions.⁷

All ice hockey injuries requiring medical attention, resulting in the inability to complete a session, and/or time loss from hockey were identified by the team designate or therapist and recorded on an injury report form. Concussions were included if they met the reportable injury definition for this

study based on the therapist assessment and definition for concussion based on consensus guidelines.¹⁵ The study definition for severe injury was based on time loss. Considering all injuries (including concussion), severe injuries were those that resulted in more than 1 week missed from hockey (ie, does not include slight and minimal injuries based on previous consensus agreement for injury definitions).¹⁷ All concussions included severe concussions that resulted in time loss from hockey of more than 10 days. A 10-day time-loss cutpoint has been suggested as a marker to retrospectively distinguish concussion severity and has been supported in the literature for male sport participants.^{15,18-22} Any study therapist not present at the time of injury was notified by the team designate, and the injured player was assessed at the next weekly visit to the team.

All players with a suspected concussion or an injury resulting in time loss greater than 1 week were recommended for review by a study sport medicine physician. Standardized follow-up and return-to-play guidelines were followed by all study physicians and study therapists, based on International Concussion Consensus guidelines.¹⁵ This included graded symptom-free exertion prior to full return to unrestricted competition. In the event that parents elected to follow up with their own family physician, standardized physician follow-up was not ensured, but study therapist recommendations were consistent with guidelines.

All injury report forms were reviewed by the research coordinators (also physiotherapists or athletic therapists) to ensure they met the injury criteria and to provide follow-up until complete recovery prior to inclusion in the database.

In addition to the primary risk factor under consideration (ie, participation in a league permitting vs not permitting body checking), we examined the role of other previously suggested risk factors. The information for these were obtained by self-report at base-

line and included year of play (first or second), previous injury or concussion, weight, level of play (leagues are divided into levels according to ability), predicted primary position of play, and attitudes toward body checking.^{7,23,24} Weight was dichotomized at the 25th percentile (37 kg) using these data based on the a priori consideration that the smallest players would be at greatest risk of injury. Attitude toward body checking was dichotomized at the 75th percentile using these data (36/55 items on a body-checking questionnaire) based on the a priori consideration that players with higher total scores would be at the greatest risk of injury.

Statistical Analysis

Stata version 10.0 was used for all statistical analyses.²⁵ Baseline characteristics were compared between Alberta and Quebec.

Incidence rate ratios for each risk factor for the primary outcomes of injury and concussion were estimated with 95% confidence intervals using Poisson regression. In each model, player-hours were included as an offset; clustering by team effect was accounted for with adjustment for all included covariates (year of play, previous injury or concussion, player size, level of play, position, and attitudes toward body checking). Sex was not considered a covariate in any model.

Because of the smaller event rates for the secondary outcomes of severe injury and severe concussion, we limited the Poisson regression to univariate analyses for each risk factor separately (still including player-hours as an offset and accounting for clustering effects by team). Given the expectation of effect modification by session type (game vs practice), analyses were stratified by this variable for all injury definitions. Significance was based on $\alpha < .05$, and all hypothesis tests were 2-sided.

RESULTS

A total of 183 teams were approached to participate in the study (90 in

Alberta and 93 in Quebec), with 162 teams (88.5%) agreeing to participate (75 [83.3%] in Alberta and 87 [93.6%] in Quebec). The reasons for nonparticipation were primarily at the team level and included the inability to identify a team designate, team therapist, or a coach decision not to participate. Seventy-four Pee Wee teams from Alberta ($n=1108$ players; 821 in Calgary and 287 in Edmonton) and 78 Pee Wee teams from Quebec ($n=1046$ players; 567 in Montreal and 479 in Quebec City) completed this study. One team from Alberta and 9 teams from Quebec dropped out of the study based on team decision or the inability to secure a study therapist. The mean number of players participating in the study from each team was 15 (range, 6-19) in Alberta and 13 (range, 4-17) in Quebec.

TABLE 1 summarizes baseline characteristics. The distributions of sex, height, weight, year of play, level of play, and position of play in the 2 provinces were similar. There were greater proportions of players reporting previous injury and previous concussion in Alberta compared with Quebec. Player attitudes toward body checking suggested a stronger preference for body checking in Alberta.

The median (interquartile range [IQR]) individual total season game and practice exposure-hours were similar in Alberta and Quebec (43 [IQR, 37-52] and 48 [IQR, 39-57] game-hours, respectively; 32 [IQR, 26-38] and 26 [IQR, 18-40] practice-hours). Although similar between provinces, the IQRs for total game- and practice-hours suggest significant variability (37-57 and 18-40, respectively). Because of some missing weekly exposure information, we imputed some of these data. In Alberta, the proportion of weeks for which exposure-hours required imputation was 10.91%. In Quebec, the proportion of weeks in which exposure-hours were imputed was 17.25%.

There were a total of 241 injuries (78 concussions) reported in Alberta in 85 077 player exposure-hours and 91

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injuries (23 concussions) reported in Quebec in 82 099 player exposure-hours. In Alberta, 169 players had 1 in-

jury, 31 players had 2 injuries, 2 players had 3 injuries, and 1 player had 4 injuries. In Quebec, 73 players had 1

injury, 6 players had 2 injuries, and 2 players had 3 injuries. Injury rates were stratified by session type (game and practice).

The province-specific injury rates and the comparative IRRs are summarized for game-related injuries in TABLE 2. The unadjusted IRRs comparing Alberta with Quebec were 3.07 for game-related injuries, 3.30 for severe injuries, 3.75 for concussion, and 3.61 for severe concussion. The estimated absolute risk reduction (injuries per 1000 player-hours) that would be achieved if body checking were not permitted in Alberta was 2.84 for game-related injuries, 0.72 for severe injuries, 1.08 for concussion, and 0.20 for severe concussion. There were no differences between provinces with respect to practice-related injuries. The proportion of players who had 2 or more independent game injuries was 2.17% (95% confidence interval [CI], 1.41%-3.33%) in Alberta and 0.38% (95% CI, 0.14%-0.97%) in Quebec. The proportion of players who had 1 or more independent practice injuries was similar in Alberta and Quebec (2.62% [95% CI, 1.70%-4.02%] and 1.91% [95% CI, 1.11%-3.29%], respectively).

TABLE 3 summarizes results for game-related injury risk factors including province, using the adjusted multiple Poisson regression models for the primary outcomes of injury and concussion and unadjusted models for secondary outcomes of severe injury and severe concussion. Players with miss-

Table 1. Baseline Characteristics Comparing Pee Wee (11-12 Years) Hockey Players in Alberta and Quebec, 2007-2008

Characteristic	No. (%)			
	Injured		Not Injured	
	Alberta (n = 203)	Quebec (n = 81)	Alberta (n = 905)	Quebec (n = 965)
Sex				
Male	201 (99.01)	79 (98.75)	888 (98.45)	949 (98.34)
Female	2 (0.99)	1 (1.25)	14 (1.55)	16 (1.66)
Height, mean (SD), cm	151.4 (9.0)	151.7 (8.8)	151.9 (8.8)	152.5 (8.5)
Missing data	15 (7.4)	2 (2.5)	84 (9.3)	12 (1.2)
Weight, mean (SD), kg	43.3 (8.3)	43.9 (9.2)	43.1 (8.4)	44.4 (9.0)
Missing data	14 (6.9)	1 (1.2)	74 (8.2)	6 (0.6)
Year of play				
First	98 (48.3)	25 (30.9)	392 (43.3)	403 (41.8)
Second	105 (51.7)	53 (65.4)	500 (55.2)	541 (56.1)
Missing data	0	3 (3.7)	13 (1.4)	21 (2.2)
Level of play				
Upper (top 20%)	108 (53.2)	34 (42.0)	587 (64.9)	622 (64.5)
Lower (mid 40%)	95 (46.8)	47 (58.0)	318 (35.1)	343 (35.5)
Position				
Forward	124 (61.1)	46 (56.8)	499 (55.1)	539 (55.9)
Defense	66 (32.5)	26 (32.1)	266 (29.4)	307 (31.8)
Goalie	10 (4.9)	7 (8.6)	123 (13.6)	106 (11.0)
Missing data	3 (1.5)	2 (2.5)	17 (1.9)	13 (1.3)
Previous injury				
Yes	66 (32.5)	24 (29.6)	152 (16.8)	144 (14.9)
No	133 (65.5)	56 (69.1)	724 (80.0)	817 (84.7)
Missing data	4 (2.0)	1 (1.2)	29 (3.2)	4 (0.4)
Previous concussion				
Yes	49 (24.1)	23 (28.4)	148 (16.4)	108 (11.2)
No	147 (72.4)	56 (69.1)	733 (81.0)	850 (88.1)
Missing data	7 (3.4)	2 (2.5)	24 (2.7)	7 (8.0)
Attitude toward body checking total score, mean (SD), XX/55 items	35.3 (5.7)	27.4 (7.1)	34.8 (5.8)	26.0 (6.5)
Missing data	6 (3.0)	6 (7.4)	91 (10.1)	82 (8.5)

Table 2. Summary of Outcome Variables for Pee Wee Ice Hockey Injuries in Alberta and Quebec (2007-2008)

Outcome	Injury		Severe Injury		Concussion		Severe Concussion	
	Alberta	Quebec	Alberta	Quebec	Alberta	Quebec	Alberta	Quebec
No. of injuries or concussions	209	70	51	16	73	20	14	4
Athlete participation, h	49 687	51 103	49 687	51 103	49 687	51 103	49 687	51 103
Injury rate, injuries per 1000 player-hours (95% CI)	4.20 (3.49-5.07)	1.37 (1.04-1.80)	1.03 (0.73-1.46)	0.31 (0.19-0.53)	1.47 (1.08-1.99)	0.39 (0.23-0.67)	0.28 (0.15-0.53)	0.08 (0.03-0.20)
Incidence rate ratio ^a	3.07 (2.21-4.27)	1 [Reference]	3.30 (1.77-6.17)	1 [Reference]	3.75 (2.02-6.98)	1 [Reference]	3.61 (1.16-11.23)	1 [Reference]
Absolute risk reduction if checking were not permitted, injuries per 1000 player-hours (95% CI)	2.84 (2.18-3.49)		0.72 (0.40-1.04)		1.08 (0.70-1.46)		0.20 (0.04-0.37)	

Abbreviation: CI, confidence interval.

^aRatios based on Poisson regression analysis offset for exposure hours, adjusted for clustering by team, unadjusted for covariates.

ing covariates were excluded in the adjusted model. Previous injury and previous concussion were risk factors for injury and concussion, respectively. Small player size and higher levels of play were also risk factors for all injuries; however, for concussion and severe concussion there was uncertainty because of the small number of events. Position played and attitude toward body checking were also significantly associated with severe concussion only.

Injury rates by mechanism of game injury and province are summarized in the FIGURE. Examining mechanism of injury in Alberta, the game-injury rate associated with body checking was higher (2.72 [95% CI, 2.21-3.35] injuries per 1000 player-hours) than any of the other mechanisms (0.24-0.46). In Quebec, incidental contact

led to the highest injury rate (0.49 [95% CI, 0.32-0.74] injuries per 1000 player-hours) compared with the other mechanisms (0.20-0.24). The injury rate attributable to other intentional contact in Alberta (0.46 [95% CI, 0.29-0.73] injuries per 1000 player-hours) was twice that found in Quebec (0.22 [95% CI, 0.10-0.47]). The injury rates associated with other mechanisms (ie, environmental contact, no contact) were similar in the 2 provinces.

By specific body part, the game-injury rates in Alberta were consistently greater than those in Quebec (TABLE 4). The head or face was the most frequently injured body part in Alberta, followed by the knee and the shoulder or clavicle. In Quebec, injuries to the head or face and the knee were the most frequent, followed by in-

juries to the hip or thigh. In examining injury types (Table 4), concussion had the highest incidence among other types of injury in Alberta and the greatest disparity by province. Fractures were the other injury type with the greatest disparity between provinces.

COMMENT

To our knowledge, this is the first prospective cohort study using a validated injury surveillance system, including therapist and physician assessment, to examine the risk of playing in an ice hockey league that permits body checking compared with one that does not. In addition, this study allowed for the estimation of IRRs for concussion and overall injury based on analyses that accounted for clustering by team, exposure-hours, and other important covariates. Our results indi-

Table 3. Risk Factor Analyses for Game-Related Injury, Severe Injury, Concussion, and Severe Concussion in Pee Wee Ice Hockey in Alberta and Quebec (2007-2008)

Risk Factor	Incidence Rate Ratio (95% CI)			
	All Injury ^a	Severe Injury ^b	Concussion ^a	Severe Concussion ^b
Province				
Alberta	3.26 (2.31-4.60)	3.30 (1.77-6.17)	3.88 (1.91-7.89)	3.61 (1.16-11.23)
Quebec	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Year of play				
First	1.04 (0.80-1.36)	0.75 (0.45-1.23)	1.03 (0.62-1.70)	0.57 (0.14-2.36)
Second	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Previous injury				
Yes	2.07 (1.49-2.86)	3.78 (2.36-6.06)	NA	NA
No	1 [Reference]	1 [Reference]	NA	NA
Previous concussion				
Yes	NA	NA	2.14 (1.28-3.55)	2.76 (1.10-6.91)
No	NA	NA	1 [Reference]	1 [Reference]
Player size				
Low weight (≤37 kg)	1.40 (1.01-1.93)	1.19 (0.69-2.05)	1.32 (0.78-2.23)	0.69 (0.23-2.09)
High weight (>37 kg)	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Level of play				
Upper (top 20%)	1.46 (1.06-2.03)	1.81 (0.99-3.32)	1.28 (0.75-2.17)	0.83 (0.30-2.31)
Lower (mid 40%)	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Position				
Defense	0.89 (0.66-1.20)	0.74 (0.44-1.24)	1.00 (0.62-1.60)	0.22 (0.06-0.84)
Goalie	0.58 (0.33-1.02)	0.12 (0.02-0.86)	0.51 (0.16-1.64)	0
Forward	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Attitudes toward body checking ^c				
High (≥36/55 items)	0.89 (0.69-1.15)	1.73 (1.05-2.83)	0.99 (0.61-1.60)	2.52 (1.00-6.35)
Low (<36/55 items)	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]

Abbreviations: CI, confidence interval; NA, not applicable (based on examining the risk factor of interest for all previous injury for injury definitions and for previous concussion for concussion definitions).

^aIncidence rate ratios based on Poisson regression analysis offset for exposure hours and adjusted for clustering by team and covariates (year of play, previous injury or concussion, player size, level of play, position of play, and attitudes toward body checking).

^bIncidence rate ratios based on Poisson regression analysis offset for exposure hours and adjusted only for clustering by team, owing to fewer injuries.

^cHigh scores on the Body Checking Questionnaire suggest a greater preference to body check.

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cate a greater than 3-fold increased risk of concussion, injury, severe concussion, and severe injury in game play in Pee Wee (ages 11-12 years) leagues in which body checking was permitted (Alberta) compared with similar leagues by level of play in which body checking was not permitted (Quebec). There was no evidence of a difference in practice-related injury rates between provinces. Other potential models—zero-inflated Poisson, quasi Poisson, and negative binomial—did not lead to different results.

Our findings support those from recent systematic reviews examining risk factors for injury in youth ice hockey that examine data from less rigorous methodological and retrospective study designs.^{23,24} Warsh et al²³ concluded that increased injuries attributable to body checking were found where body checking was allowed. Emery et al²⁴ combined data examining the risk of body-checking policy in youth ice hockey in a meta-analysis and reported combined estimates for injury (IRR, 2.45 [95% CI,

1.7-3.6]) and concussion (odds ratio, 1.71 [95% CI, 1.2-2.44]).

The overall injury and concussion rate found in Alberta in this study are consistent with the literature.^{8,26} Mechanisms of injury, body part, and injury types were also consistent. The greatest disparity in injury rates between provinces was for concussions and fractures—not surprising, given the mechanics of body checking. Other than the significantly increased risk of injuries related to body-checking mechanism, there was also a 2-fold increased risk of other intentional contact injuries in Alberta compared with Quebec, suggesting a more aggressive style of play in which body checking is permitted.

Consistent with the literature, previous injury and concussion increased the risk of injury and concussion, respectively.²⁷ This may be related to incomplete healing/rehabilitation, susceptibility of a player to injury based on other factors (eg, on-ice behaviors), or both.

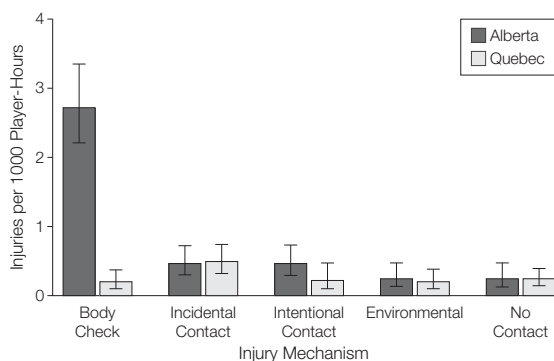
Smaller player size was also a risk factor for all injuries. This may be owing to the contact mechanisms of injury reported in both cohorts and the size differential between players participating in these leagues. Lighter players have previously been reported to be at a greater risk of injury in youth ice hockey leagues.^{6,28}

Limitations

Recruitment rates were similar between provinces, but a greater number of teams dropped out in Quebec (n=9) compared with Alberta (n=1). However, given that dropouts were at a team level and the reasons for dropouts were related to the inability to identify a therapist or team designate, one would not expect a systematic selection bias associated with dropout.

With a therapist present at only 1 session each week, it is possible that minor injuries may have been underestimated if the team designate was not aware of the injury. However, in the weekly follow-up the therapist was to communicate with the team designate

Figure. Game-Related Injury Rates by Injury Mechanism and Province in Pee Wee Ice Hockey, Alberta and Quebec (2007-2008)



Error bars indicate 95% confidence intervals.

Table 4. Game-Injury Rate by Body Part and Injury Type in Alberta and Quebec (2007-2008)

	Injuries per 1000 Game-Hours (95% CI)	
	Alberta	Quebec
Body part		
Head/face	1.59 (1.19-2.12)	0.41 (0.24-0.69)
Knee	0.62 (0.43-0.90)	0.39 (0.24-0.64)
Shoulder/clavicle	0.44 (0.26-0.75)	0.04 (0.01-0.15)
Hip/groin/upper leg	0.42 (0.28-0.63)	0.16 (0.08-0.30)
Neck/throat	0.26 (0.15-0.47)	0.06 (0.02-0.18)
Back/side	0.24 (0.14-0.43)	0.08 (0.03-0.20)
Arm/elbow/forearm	0.16 (0.08-0.34)	0.04 (0.01-0.15)
Lower leg/ankle/foot	0.16 (0.08-0.33)	0.14 (0.06-0.34)
Wrist/hand	0.16 (0.08-0.31)	0.04 (0.01-0.16)
Ribs/abdomen/pelvis	0.14 (0.06-0.31)	0.02 (0.003-0.14)
Injury type		
Concussion	1.47 (1.08-1.99)	0.39 (0.23-0.67)
Contusion	1.17 (0.86-1.59)	0.37 (0.22-0.63)
Muscle strain/tendonitis	0.70 (0.51-0.98)	0.18 (0.10-0.32)
Joint/ligament sprain/dislocation	0.36 (0.23-0.58)	0.25 (0.16-0.42)
Fracture	0.34 (0.20-0.57)	0.06 (0.01-0.25)
Abrasion/bleeding/burn/cut	0.04 (0.01-0.16)	0.04 (0.01-0.15)
Other	0.08 (0.03-0.21)	0.08 (0.02-0.26)

Abbreviation CI, confidence interval.

and players to reduce the number of missed injuries. In addition, it is unlikely this reporting issue differed by province.

Concussions were included if they met the injury and concussion definitions based on study therapist injury report. It is a limitation, however, that not all players followed up with a physician. In Alberta, 39 of 78 (50% [95% CI, 38.5%-61.5%]) players with reported concussion saw a physician, compared with 14 of 23 (60.9% [95% CI, 38.5%-80.3%]) in Quebec. Given that the proportions of players with concussion following up with physicians did not differ between provinces, it is unlikely that bias was introduced in the estimates of IRRs associated with concussion.

This study aimed to collect both the exact number of sessions missed from hockey (assessed using the weekly exposure sheet) and the total number of days a participant was unable to play hockey (assessed using the injury report form). Many different factors contribute to this decision, such as the importance of a game or practice, pain tolerance, motivation, personality factors, and parental influence. These differ for each player and may affect the precision of equating time loss with severity of injury. Guidelines for return to play established based on the Concussion Consensus Guidelines facilitated consistency for return to play following concussion between centers.¹⁵ However, it is possible that there was nondifferential misclassification of concussion severity based on the 10-day time-loss cutpoint if there was a delay of more than 4 days until the athlete had first seen a physician and then progressed through the return-to-play protocol.

The reasons for missing data on the weekly exposure sheet (10.91% in Alberta, 17.25% in Quebec) were related to team designate error and not to participation-hours, injury, or any confounding factors. As such, the missing mechanism is arguably missing completely at random, and there is no reason to suspect that the infor-

mation on missing weeks differed from that on weeks for which values were present.

Baseline risk factors were self-reported and are subject to nondifferential misclassification. In particular, the position of play may not have been consistent for every game during the season.

Rules of play and referee qualifications did not differ between provinces other than the rule allowing body checking in Alberta and not in Quebec; however, the reward systems for Fair-Play Programs did differ in Alberta and Quebec. In Quebec and in Edmonton, Alberta, reward systems were based on the number of penalty minutes called by referees. While there was an emphasis on Fair-Play conduct also in Calgary, Alberta, there was no official reward system in place. Although the Fair-Play systems differed, in Calgary and Edmonton the injury rates did not differ (Calgary, 2.79 [95% CI, 2.28-3.40] injuries per 1000 player-hours; Edmonton, 2.94 [95% CI, 2.04-4.23]). This strengthens the conclusion that our results did not depend on differences between provinces in the Fair-Play Programs. Consistent with this, there is also evidence in the literature that injury rates and the observed number of transgressions does not differ in a Bantam League that rewards teams through a Fair-Play point system for low penalty minutes compared with a Bantam League with no reward system (body checking allowed in both leagues).²⁹

CONCLUSION

Among 11- to 12-year-old ice hockey players, playing in a league in which body checking is permitted compared with a league in which body checking is not permitted was associated with a 3-fold increased risk of all game-related injuries, concussion, severe injury, and severe concussion. These findings may have important implications for policy decisions related to body checking in youth ice hockey. The public health implications associ-

ated with injury in Pee Wee hockey in which body checking is permitted are significant. Future research should compare the injury and concussion risk in the next age group of play (Bantam, ages 13-14 years), in which players in one cohort will have 2 years of body checking experience prior to Bantam participation. This research can inform the development and rigorous evaluation of prevention strategies to reduce the risk of injury in this population of youth ice hockey participants.

Author Contributions: Dr Emery had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Emery, Shrier, Goulet, Hagel, Benson, Nettel-Aguirre, Meeuwisse.

Acquisition of data: Emery, Shrier, Goulet, McAllister, Meeuwisse.

Analysis and interpretation of data: Emery, Kang, Shrier, Goulet, Hagel, Benson, McAllister, Hamilton, Meeuwisse.

Drafting of the manuscript: Emery, Kang, Shrier, Benson, McAllister, Hamilton, Meeuwisse.

Critical revision of the manuscript for important intellectual content: Emery, Kang, Shrier, Goulet, Hagel, Benson, Nettel-Aguirre, Hamilton.

Statistical analysis: Kang, Shrier, Nettel-Aguirre, Hamilton, Meeuwisse.

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Administrative, technical, or material support: Kang, Goulet, Benson, McAllister, Hamilton.

Study supervision: Emery, Goulet, Meeuwisse.

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REFERENCES

- Hockey Canada Annual Report 2008. Hockey Canada Web site. http://www.hockeycanada.ca/index.php/ci_id/55192/la_id/1.htm. Accessed February 18, 2010.
- Hockey Annual Report USA 2007/2008. USA Hockey Web site. http://www.usahockey.com/uploadedFiles/USAHockey/Menu_About_USA_Hockey/USAH%20Annual%20Report%200708_WEB.pdf. Accessed February 18, 2010.
- Emery CA, Meeuwisse WH, McAllister JR. Survey of sport participation and sport injury in Calgary and area high schools. *Clin J Sport Med*. 2006;16(1):20-26.
- Emery CA, Tyreman H. Sport participation, sport injury, risk factors and sport safety practices in Calgary and area junior high schools. *Paediatr Child Health (Oxford)*. 2009;14(7):439-444.
- Benson B, Meeuwisse W. The risk of concussion associated with mouthguard use among professional ice hockey players [abstract]. *Clin J Sport Med*. 2005;15(5):395.
- Brust JD, Leonard BJ, Pheley A, Roberts WO. Children's ice hockey injuries. *Am J Dis Child*. 1992;146(6):741-747.
- Emery CA, Meeuwisse WH. Injury rates, risk factors, and mechanisms of injury in minor hockey. *Am J Sports Med*. 2006;34(12):1960-1969.
- Roy M, Bernard D, Roy B, Marcotte G. Body checking in Peewee Hockey. *Phys Sportsmed*. 1989;17(3):119-126.
- Marchie A, Cusimano MD. Bodychecking and concussions in ice hockey: should our youth pay the price? *CMAJ*. 2003;169(2):124-128.
- Roberts WO, Brust JD, Leonard B. Youth ice hockey tournament injuries: rates and patterns compared to season play. *Med Sci Sports Exerc*. 1999;31(1):46-51.
- 2007-09 Official Rules of Ice Hockey. USA Hockey Web site. http://www.usahockey.com/uploadedfiles/usahockey/menu_officials/menu_rulesequipment/rulebook%200709.pdf. 2007. Accessed January 19, 2010.
- Background on checking. Hockey Canada Web site. <http://www.hockeycanada.ca>. Accessed February 18, 2010.
- Hayes RJ, Bennett S. Simple sample size calculations for cluster-randomized trials. *Int J Epidemiol*. 1999;28(2):319-326.
- Meeuwisse WH, Love EJ. Development, implementation, and validation of the Canadian Intercollegiate Sport Injury Registry. *Clin J Sport Med*. 1998;8(3):164-177.
- McCrorry P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med*. 2005;39(4):196-204.
- Emery CA, McKay CD, Campbell TS, Peters AN. Examining attitudes towards body-checking, levels of emotional empathy, and levels of aggression in body-checking and non-body checking youth hockey leagues. *Clin J Sport Med*. 2009;19(3):207-215.
- Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clin J Sport Med*. 2006;16(2):97-106.
- McCrorry P, Meeuwisse W, Johnston K, et al. Consensus statement on concussion in sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *Br J Sports Med*. 2009;43(suppl 1):i76-i90.
- Broglio SP, Puetz TW. The effect of sport concussion on neurocognitive function, self-report symptoms and postural control: a meta-analysis. *Sports Med*. 2008;38(1):53-67.
- Iverson G. Predicting slow recovery from sport-related concussion: the new simple-complex distinction. *Clin J Sport Med*. 2007;17(1):31-37.
- Lau B, Lovell M, Collins M, Pardini J. Neurocognitive and symptom predictors of recovery in high school athletes. *Clin J Sport Med*. 2009;19(3):216-221.
- Makdissi M. Is the simple versus complex classification of concussion a valid and useful differentiation? *Br J Sports Med*. 2009;43(suppl 1):i23-i27.
- Warsh JM, Constantin SA, Howard A, Macpherson A. A systematic review of the association between body checking and injury in youth ice hockey. *Clin J Sport Med*. 2009;19(2):134-144.
- Emery CA, Hagel B, Decloe MD, McKay C. Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. *Inj Prev*. 2010;16(2):113-118.
- Stata Statistical Software [computer program]. Version 10.0. College Station, TX: StataCorp; 2005.
- Willer B, Kroetsch B, Darling S, Hutson A, Leddy J. Injury rates in house league, select, and representative youth ice hockey. *Med Sci Sports Exerc*. 2005;37(10):1658-1663.
- Emery CA. Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clin J Sport Med*. 2003;13(4):256-268.
- Wiggins W. *Implication of Introducing Body-Checking in Ice Hockey at Different Ages* [master's thesis]. Thunder Bay, ON, Canada: Lakehead University; 1999.
- Brunelle JP, Goulet C, Arguin H. Promoting respect for the rules and injury prevention in ice hockey: evaluation of the fair-play program. *J Sci Med Sport*. 2005;8(3):294-304.

I never taught language for the purpose of teaching it; but invariably used language as a medium for the communication of thought; thus learning of language was coincident with the acquisition of knowledge.

—Anne Sullivan (1866-1936)