No association found between body checking experience and injury or concussion rates in adolescent ice hockey players

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ABSTRACT

Objectives To compare rates of injury and concussion among U-15 (ages 13–14 years) ice hockey players playing in leagues allowing body checking, but who have a varying number of years of body checking experience.

Methods This 5-year longitudinal cohort included U-15 ice hockey players playing in leagues where policy allowed body checking. Years of body checking experience were classified based on national/local body checking policy. All ice hockey game-related injuries were identified using a validated injury surveillance methodology. Players with a suspected concussion were referred to a study sport medicine physician. Multiple multilevel Poisson regression analysis was performed, adjusting for important covariates and a random effect at a team level (offset by game exposure hours), to estimate injury and concussion incidence rate ratios (IRRs).

Results In total, 1647 players participated, contributing 1842 player-seasons (195 players participating in two seasons). Relative to no body checking experience, no significant differences were found in the adjusted IRRs for game-related injury for players with 1 year (IRR=1.06; 95% CI: 0.77 to 1.45) or 2+ years (IRR=1.16; 95% CI: 0.74 to 1.84) body checking experience. Similarly, no differences were found in the rates of concussion for players with 1 year (IRR=0.92; 95% CI: 0.59 to 1.42) or 2+ years (IRR=0.69; 95% CI: 0.38 to 1.25) body checking experience.

Conclusions Among ice hockey players aged 13–14 years participating in leagues permitting body checking, the adjusted rates of all injury and concussion were not significantly different between those that had body checking experience and those that did not. Based on these findings, no association was found between body checking experience and rates of injury or concussion specifically in adolescent ice hockey.

INTRODUCTION

Ice hockey is a very popular sport in Canada with over 500,000 youth under 18 years of age participating in 2018.1 Over 72,500 players were registered in the U-15 age category (ages 13–14 years; formerly called Bantam).2 The benefits to participating in sports such as ice hockey are numerous and include improved physical fitness, self-esteem and mental health.3,4 Regrettably, participation in youth ice hockey is also associated with a high burden of injury. It is among the top three injury-producing sports in youth in Canada and accounts for over 10% of all youth sport-related injuries.5 In youth leagues permitting body checking, the rates of injury are estimated to be as high as 7.98 injuries/1000 game-hours and 3.34 concussions/1000 game-hours.6,7

Body checking is a tactic used in ice hockey when a player intentionally makes body contact with an opponent using their body to stop an attacking player and/or to separate the opponent from the puck.8 Research has informed body checking policy change to not permit body checking in games at the U-13 (ages 11–12 years; formerly called Pee Wee) level nationally (USA Hockey 2011, Hockey Canada 2013), as well as in non-elite divisions of play in older age categories (ages 13–17 years).9–13

In evaluation of these policy changes, disallowing body checking in games was associated with a 50% and 64% reduction in the rate of all injury and concussion in U-13 players, respectively.14 Reduced injury rates have also been found in the non-elite U-15 and U-18 (ages 15–17 years; formerly called Midget) age categories.15,16 It is critical, however, to inform national and regional ice hockey associations regarding a greater understanding of any unintended consequences of such policy change. Unintended consequences of any injury prevention strategy have been an ongoing priority of the international injury prevention and concussion research and practice community.17–21

Despite the evidence, proponents for permitting body checking argue that gaining body checking experience earlier may protect players from injuries in the later age categories. That is, they argue that introducing body checking at the U-13 level would protect players who continued to participate in the U-15 level where players are older and presumably bigger and faster. A previous prospective cohort study based on the 2008/09 season of play compared U-15 players in the top 30% by division of play who had 2 years of body checking experience at the U-13 level with players who had no prior body checking experience. This study suggested similar overall injury (incidence rate ratio (IRR)=0.85; 95% CI: 0.63 to 1.16) and concussion rates (IRR=0.84; 95% CI: 0.48 to 1.48) between these two groups, although the rate of injury resulting in time-loss >7 days was 33% lower among those that had body checking experience at the U-13 level than those who did not (IRR=0.67; 95% CI: 0.46 to 0.99).22 However, it is important to highlight that this finding should be interpreted alongside the research evaluating body


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checking policy change reducing the rate of injury resulting in >7 days of time-loss by 60% in U-13 leagues disallowing body checking.14

The body checking policy changes nationally in U-13 and at non-elite levels (lower 70% by division of play) in U-15 in some jurisdictions has presented a unique opportunity to evaluate the association of body checking experience and rates of injury and concussion in the U-15 age category in a larger, more recently obtained sample. In addition, it is important to evaluate and ensure that there are no unintended injury consequences after a governing body implements rule changes. This is because every decision, even if intended as an injury preventative measure, may produce unintended ‘side effects’ or consequences including a potential increased risk of injury in the same or a different population.17 19 23 As such, the objective of this study was to compare rates of injury and concussion, adjusted for other important covariates, among U-15 (ages 13–14 years) ice hockey players participating in leagues allowing body checking, but who have a varying number of years of body checking experience. This evaluation will provide important evidence for the recent and any future body checking policy decisions that may be implemented in youth ice hockey. We hypothesised that no association would be found between years of body checking experience and rates of injury or concussion.

**METHODS**

**Design**

This was a prospective cohort study conducted over five seasons of play (2013/14 to 2017/18) and included U-15 leagues permitting body checking in three cities from two provinces (British Columbia (Vancouver) and Alberta (Calgary, Edmonton)).

**Participants**

The study population included U-15 players (ages 13–14 years) across all levels of play participating in leagues permitting body checking. Recruitment numbers varied by city and year as body checking policy changed throughout the study period (table 1). While no a priori sample size was calculated, it was informed by a previous youth ice hockey study investigating body checking policy at the U-13 age group.24 Specifically, a sample size of 46 teams (13 players per team) was estimated based on: (1) an IRR=0.5; (2) a concussion rate=1.5/1000 player-hours in a body checking cohort; (3) 75.5 hours of exposure; (4) a team coefficient of variation of 0.58 (planned comparison rates controlling for cluster by team) (α=0.05, β=0.20) and (5) an anticipated drop-out rate of 5%.

Cohorts were defined based on their years of body checking experience. Inclusion criteria were: (1) players 13–14 years of age; (2) male or female players; (3) written informed player or parent consent; (4) players registered in U-15 with Hockey Calgary, Hockey Edmonton, Airdrie Minor Hockey or BC Hockey; (5) players participated in a league permitting body checking; (6) agreement of the head coach and (7) agreement of a team designate (eg, manager) to collect player participation and injury information. Players participating in a ‘girls-only’ league (where policy does not permit body checking) or who had a previous injury or illness that prevented full participation in hockey at the beginning of the season were excluded.

**Procedures**

The injury surveillance methodology validated in youth ice hockey included a preseason baseline questionnaire (PBQ), a weekly exposure sheet (WES) and an injury report form (IRF).8 Number of years of body checking experience was classified based on year of study and local and national body checking policy. Based on these criteria, players could have up to 3 years of body checking experience. Each team designate (eg, team manager) collected WES information and identified players with an injury or suspected concussion. A study athletic therapist and/or physiotherapist validated all injuries that were reported by the team designate on the IRF. The details of this validated injury surveillance system have been previously published.8 13 14 22 All ice hockey injuries resulting in medical attention, the inability to complete a session and/or time-loss from hockey were identified by the team designate and recorded on an IRF. Every player with a suspected concussion could follow-up with a study sport medicine physician within 72 hours. Standardised follow-up and return to play protocols were followed by all study physicians based on the fourth International Consensus Statement on Concussion in Sport.24 Conclusions that met the definition based on the Consensus Statement on Concussion in Sport were included.21 Further, injuries that resulted in >7 days of time-loss and concussions that resulted in >10 days of time-loss were included as outcomes. The use of a 7-day time-loss cut-point for injury and 10-day time-loss cut-point for concussion have been supported by previous consensus statements and allows for comparison with previous youth ice hockey studies.8 12 14 20 22 23

As the body checking policy and body checking experience is based on game-related policy, game-related injury and concussion are the outcomes of interest.

**Statistical analyses**

The statistical software R (V4.0.0) and STATA (release 15) were used for all analyses.26 27 There were relatively few player-seasons with 3 years of body checking experience (n=323), so those with 2 and 3 years of body checking experience were collapsed into 2+ years. Baseline characteristics, described as frequencies and percentages or medians and quartiles, were stratified on years of body checking experience (0, 1 and 2+ years) and by players who sustained at least one game-related injury during the study period. If weekly game exposures were missing, an estimation approach based on weekly means was performed within participant, or based on team information, or within city and division as informed by previous youth ice hockey studies and methodological approach as recommended by Kang et al.7 12 14 28 Crude game-related injury rates (offset for game-hours) were estimated for injury, injury resulting in >7 days of time-loss, all concussion and concussion resulting in >10 days of time-loss for each study group with 95% Poisson CIs adjusted for cluster by team and individual. Absolute risk reductions (ARR) were calculated based on these injury rates and 95% CIs adjusted for cluster. Crude IRRs with corresponding 95% CIs were estimated using multilevel Poisson regression with one random effect at the team level and one random effect at the individual level (offset by game-hours).

Separate multiple multilevel Poisson regression models for game-related injury, injury resulting in >7 days of time-loss, concussion and concussion resulting in >10 days of time-loss were used to evaluate the association between years of body checking experience and each outcome. The regression models were adjusted for the following previously identified and potentially confounding covariates: any previous injury in the last 12 months (for the injury outcomes), previous lifetime concussion history (for the concussion outcomes), year of play (first or second), player weight (categorised based on the pattern observed between log (rate) and weight when assumption of
Table 1  Baseline characteristics for U-15 ice hockey players’ years of BC experience over five seasons (2013–2018)

<table>
<thead>
<tr>
<th></th>
<th>0 years BC experience</th>
<th>1 year BC experience</th>
<th>2+ years BC experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured (n=118*)</td>
<td>Not injured (n=439*)</td>
<td>Injured (n=121*)</td>
</tr>
<tr>
<td>City, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calgary</td>
<td>86 (72.88)</td>
<td>315 (71.25)</td>
<td>85 (70.25)</td>
</tr>
<tr>
<td>Edmonton</td>
<td>32 (27.12)</td>
<td>124 (28.25)</td>
<td>24 (19.83)</td>
</tr>
<tr>
<td>Vancouver</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>12 (9.92)</td>
</tr>
<tr>
<td>Years, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013–14</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>2014–15</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>62 (51.24)</td>
</tr>
<tr>
<td>2015–16</td>
<td>58 (49.15)</td>
<td>207 (47.15)</td>
<td>25 (20.66)</td>
</tr>
<tr>
<td>2016–17</td>
<td>30 (25.42)</td>
<td>133 (30.30)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>2017–18</td>
<td>30 (25.42)</td>
<td>99 (22.55)</td>
<td>34 (28.10)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>118 (100.00)</td>
<td>434 (98.86)</td>
<td>118 (97.52)</td>
</tr>
<tr>
<td>Female</td>
<td>0 (0.00)</td>
<td>4 (0.91)</td>
<td>3 (2.48)</td>
</tr>
<tr>
<td>Missing</td>
<td>0 (0.00)</td>
<td>1 (0.23)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>Anthropometrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height, cm, median (Q1, Q3)</td>
<td>161.70 (154.90, 169.90)</td>
<td>163.50 (157.50, 170.95)</td>
<td>167.00 (159.10, 172.90)</td>
</tr>
<tr>
<td>Weight, kg, median (Q1, Q3)</td>
<td>49.90 (43.20, 59.00)</td>
<td>51.40 (45.40, 58.95)</td>
<td>55.10 (47.62, 61.37)</td>
</tr>
<tr>
<td>Level of play, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elite (top 20%)</td>
<td>91 (77.12)</td>
<td>359 (81.78)</td>
<td>83 (68.60)</td>
</tr>
<tr>
<td>Subelite (lower 80%)</td>
<td>27 (22.88)</td>
<td>80 (18.22)</td>
<td>38 (31.40)</td>
</tr>
<tr>
<td>Position, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>73 (61.86)</td>
<td>238 (54.21)</td>
<td>67 (55.37)</td>
</tr>
<tr>
<td>Defence</td>
<td>34 (28.81)</td>
<td>137 (31.21)</td>
<td>45 (37.19)</td>
</tr>
<tr>
<td>Goalie</td>
<td>6 (5.08)</td>
<td>42 (9.57)</td>
<td>7 (5.79)</td>
</tr>
<tr>
<td>Position, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous injury†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>52 (44.07)</td>
<td>190 (43.28)</td>
<td>52 (42.98)</td>
</tr>
<tr>
<td>Yes</td>
<td>40 (33.90)</td>
<td>144 (32.80)</td>
<td>52 (42.98)</td>
</tr>
<tr>
<td>Missing</td>
<td>26 (2.03)</td>
<td>105 (23.92)</td>
<td>17 (14.05)</td>
</tr>
</tbody>
</table>

Q1: first quartile; Q3: third quartile.
*Sum of n is 1842, given that it is player-season (195 players participated in more than one season).
†Previous injury or concussion 12 months prior to baseline test.
‡Previous concussion ever.
BC, body checking.
linearity was not met), level of play (elite divisions of play (top 20% by division of play) and subelite (lower 80%)) and position (forward, defence or goalie). Player game-hours was used as an offset in the models and random effects at the team and individual level were examined to account for clustering. Missing data were imputed using multiple multilevel imputation using chained equations with 30 imputations completed. Sex was not considered due to the low numbers of female player-seasons (n=29).

Crude injury rates by body location and injury type were calculated with 95% exact Poisson CIs based on multilevel Poisson regression with one random effect at the team level (offset by game-hours). BC, body checking; IRR, incidence rate ratio.

**RESULTS**

In total, 1647 unique players were recruited to participate across all sites over five seasons. Of these, 195 participated in more than one season for a combined 1842 player-seasons (557 with 0 years, 651 with 1 year and 634 with 2+ years of body checking experience). Table 1 summarises the baseline characteristics of the study cohorts by injury status (if at least one game-related injury was sustained). The median number of players recruited per team was one in those with no body checking experience and those with 1 year of experience and all injury outcomes. The crude multilevel Poisson regression models failed to converge with both random effects; therefore, only a random effect at the team level was examined for these models. Relative to no body checking experience, no differences in the crude rates were found with those with 1 year of experience for all injury (IRR=0.97; 95% CI: 0.75 to 1.28; ARR=−0.44; 95% CI: −2.70 to 1.83) and for injury resulting in >7 days of time-loss (IRR=1.04; 95% CI: 0.75 to 1.44; ARR=−0.20; 95% CI: −1.84 to 1.44). Furthermore, no differences were found with those with 2+ years of body checking experience for all injury (IRR=0.97; 95% CI: 0.74 to 1.28; ARR=1.06; 95% CI: −1.47 to 3.59) and injuries with >7 days of time-loss (IRR=0.93; 95% CI: 0.66 to 1.30; ARR=0.65; 95% CI: −1.84 to 2.50).

Concussion outcome analyses are summarised in table 3. There were no differences in the crude rates of concussion based on IRRs and ARRs (table 2) (IRR=0.98; 95% CI: 0.75 to 1.28; ARR=−0.44; 95% CI: −2.70 to 1.83) and for injury resulting in >7 days of time-loss (IRR=1.04; 95% CI: 0.75 to 1.44; ARR=−0.20; 95% CI: −1.84 to 1.44). Furthermore, no differences were found with those with 2+ years of body checking experience for all injury (IRR=0.97; 95% CI: 0.74 to 1.28; ARR=1.06; 95% CI: −1.47 to 3.59) and injuries with >7 days of time-loss (IRR=0.93; 95% CI: 0.66 to 1.30; ARR=0.65; 95% CI: −1.84 to 2.50).
Table 4  Adjusted incidence rate ratios for game-related injury and concussion outcomes for U-15 ice hockey players by years of BC experience

<table>
<thead>
<tr>
<th>Potential risk factor</th>
<th>All injury*</th>
<th>Injury &gt;7 days of time-loss*</th>
<th>Concussion†</th>
<th>Concussion &gt;10 days of time-loss†</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC experience (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>1</td>
<td>1.06 (0.77 to 1.45)</td>
<td>1.07 (0.73 to 1.57)</td>
<td>0.92 (0.59 to 1.42)</td>
<td>0.96 (0.55 to 1.68)</td>
</tr>
<tr>
<td>2+</td>
<td>1.16 (0.74 to 1.84)</td>
<td>1.02 (0.60 to 1.73)</td>
<td>0.69 (0.38 to 1.25)</td>
<td>0.80 (0.38 to 1.68)</td>
</tr>
<tr>
<td>Year of play</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First</td>
<td>1.17 (0.62 to 1.66)</td>
<td>1.09 (0.72 to 1.63)</td>
<td>0.84 (0.53 to 1.33)</td>
<td>0.83 (0.46 to 1.50)</td>
</tr>
<tr>
<td>Second</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Level of play</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elite (top 20%)</td>
<td>1.15 (0.81 to 1.62)</td>
<td>1.04 (0.72 to 1.50)</td>
<td>0.99 (0.65 to 1.51)</td>
<td>0.81 (0.48 to 1.37)</td>
</tr>
<tr>
<td>Subelit (lower 80%)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Player weight (kg)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&lt;40</td>
<td>1.64 (1.10 to 2.44)‡</td>
<td>1.40 (0.82 to 2.41)</td>
<td>1.74 (0.99 to 3.04)</td>
<td>1.91 (0.92 to 3.98)</td>
</tr>
<tr>
<td>40–79</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>80–104</td>
<td>1.20 (0.66 to 2.16)</td>
<td>1.14 (0.52 to 2.53)</td>
<td>1.21 (0.47 to 3.10)</td>
<td>1.36 (0.41 to 4.50)</td>
</tr>
<tr>
<td>Previous injury in the last year§</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Yes</td>
<td>1.30 (1.03 to 1.66)‡</td>
<td>1.35 (1.00 to 1.82)‡</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Previous concussion¶</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>NA</td>
<td>NA</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Yes</td>
<td>1.49 (1.09 to 2.04)‡</td>
<td>1.41 (0.93 to 2.13)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Position</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
<td>1 (reference)</td>
</tr>
<tr>
<td>Defence</td>
<td>0.93 (0.74 to 1.16)</td>
<td>0.98 (0.74 to 1.20)</td>
<td>1.04 (0.74 to 1.47)</td>
<td>1.19 (0.76 to 1.85)</td>
</tr>
<tr>
<td>Goallie</td>
<td>0.52 (0.32 to 0.83)‡</td>
<td>0.43 (0.22 to 0.85)‡</td>
<td>0.64 (0.32 to 1.28)</td>
<td>0.95 (0.43 to 2.10)</td>
</tr>
</tbody>
</table>

*Incidence rate ratios and corresponding 95% CI based on multiple multilevel Poisson regression analysis offset for exposure game-hours, with a random effect at a team level, and adjusted for covariates (year of play, level of play, player weight, previous injury in the last year and position). †Incidence rate ratios and corresponding 95% CI based on multiple multilevel Poisson regression analysis offset for exposure game-hours, with a random effect at a team level, and covariates (year of play, level of play, player weight, previous concussion and position). ‡Statistically significant at p<0.05. §The covariate 'previous injury in the last year' includes any concussion that occurred in the previous 12 months. ¶The covariate 'previous concussion' includes any concussion without a date limit. BC, body checking; 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).

DISCUSSION

In this prospective cohort study involving U-15 ice hockey players, the rates of all injury, injury resulting in >7 days of time-loss, all concussion and concussion resulting in >10 days of time-loss were not significantly different between those with no body checking experience and those with either 1 year or 2+ years of body checking experience. This suggests that no association was found between years of body checking experience and all injury or concussion rates, and that body checking experience does not significantly protect against injury or concussion at the U-15 age category. This is consistent with a previous cohort study that found similar rates of all injury, all concussion and concussion resulting in >10 days of time-loss among U-15 players who had 2 years of body checking experience and those that had none. The present study had contrary results in that the rate of injury resulting in >7 days of time-loss was not significantly different among the different levels of body checking experience, but previously was 33% lower among players with 2 years of body checking experience. Using a similar methodological approach, Emery et al was the first to examine body checking experience as a potential risk factor for injury and concussion, although this evaluation was limited in that the comparisons could only be made between teams in different provinces (ie, teams in Alberta with 2 years of body checking experience) and those that had none. 22

The results of the multiple multilevel Poisson regression models evaluating each game outcome and level of body checking experience are summarised in table 4. Like the crude models, the multiple multilevel models did not converge when both random effects were examined, so only the random effect by team was included. The adjusted IRRs further suggested no significant differences in the rates of any injury outcome and body checking experience accounting for 64/135 injuries (47% among all injuries) in those with no body checking experience, 61/140 (44%) among all injuries) in those with 1 year of body checking experience and 49/127 in those with 2+ years (39% among all injuries) of body checking experience.

Using a similar methodological approach, Emery et al was the first to examine body checking experience as a potential risk factor for injury and concussion, although this evaluation was limited in that the comparisons could only be made between teams in different provinces (ie, teams in Alberta with 2 years of body checking experience) and those that had none. 22
Original research

Table 5  Number and rates of game-related injuries per 1000 player-hours among U-15 ice hockey players by years of BC experience and location and injury type

<table>
<thead>
<tr>
<th>Location and type of injury</th>
<th>0 years BC experience (n=557†) Rate</th>
<th>1 year BC experience (n=651†) Rate</th>
<th>2+ years BC experience (n=634†) Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head/Face† (including concussions)</td>
<td>65 4.00 (3.03 to 5.12)</td>
<td>62 3.88 (2.89 to 5.19)</td>
<td>49 2.80 (1.90 to 4.13)</td>
</tr>
<tr>
<td>Neck/Throat</td>
<td>4 0.25 (0.07 to 0.63)</td>
<td>3 0.19 (0.04 to 0.55)</td>
<td>5 0.29 (0.09 to 0.67)</td>
</tr>
<tr>
<td>Shoulder/Clavicle†</td>
<td>16 0.99 (0.60 to 1.63)</td>
<td>19 1.19 (0.73 to 1.93)</td>
<td>15 0.86 (0.46 to 1.60)</td>
</tr>
<tr>
<td>Arm/Elbow/Forearm</td>
<td>4 0.25 (0.07 to 0.63)</td>
<td>4 0.25 (0.07 to 0.64)</td>
<td>4 0.23 (0.06 to 0.59)</td>
</tr>
<tr>
<td>Wrist/Hand†</td>
<td>11 0.68 (0.38 to 1.19)</td>
<td>9 0.56 (0.29 to 1.10)</td>
<td>12 0.69 (0.36 to 1.31)</td>
</tr>
<tr>
<td>Back/Side</td>
<td>0 0.00 (0.00 to 0.28)</td>
<td>6 0.38 (0.14 to 0.82)</td>
<td>3 0.17 (0.04 to 0.50)</td>
</tr>
<tr>
<td>Chest/Ribs/Abdomen</td>
<td>4 0.25 (0.07 to 0.63)</td>
<td>3 0.19 (0.04 to 0.55)</td>
<td>4 0.23 (0.06 to 0.59)</td>
</tr>
<tr>
<td>Pelvis/Hips/Groin/Upper leg</td>
<td>3 0.18 (0.04 to 0.54)</td>
<td>7 0.44 (0.18 to 0.90)</td>
<td>7 0.40 (0.16 to 0.82)</td>
</tr>
<tr>
<td>Knee</td>
<td>9 0.55 (0.25 to 1.05)</td>
<td>7 0.44 (0.18 to 0.90)</td>
<td>5 0.29 (0.09 to 0.67)</td>
</tr>
<tr>
<td>Lower leg/Ankle/Foot*</td>
<td>3 0.18 (0.04 to 0.54)</td>
<td>3 0.19 (0.04 to 0.55)</td>
<td>11 0.63 (0.31 to 1.12)</td>
</tr>
<tr>
<td>Other</td>
<td>3 0.18 (0.04 to 0.54)</td>
<td>1 0.06 (0.00 to 0.35)</td>
<td>0 0.00 (0.00 to 0.21)</td>
</tr>
<tr>
<td>Missing/Unknown‡</td>
<td>13 0.80 (0.44 to 1.47)</td>
<td>16 1.00 (0.55 to 1.83)</td>
<td>12 0.69 (0.39 to 1.21)</td>
</tr>
</tbody>
</table>

| Type* | 8 0.49 (0.25 to 0.96) | 12 0.75 (0.40 to 1.40) | 12 0.69 (0.35 to 1.34) |
| Concussion† | 64 3.94 (3.03 to 5.12) | 61 3.81 (2.83 to 5.13) | 49 2.80 (1.90 to 4.13) |
| Joint/Ligament sprain/Dislocation‡ | 13 0.80 (0.48 to 1.34) | 17 1.06 (0.64 to 1.76) | 14 0.80 (0.41 to 1.57) |
| Fracture† | 23 1.42 (0.94 to 2.14) | 16 1.00 (0.61 to 1.65) | 20 1.14 (0.67 to 1.95) |
| Muscle strain/Tendonitis‡ | 9 0.55 (0.30 to 1.02) | 15 0.94 (0.54 to 1.64) | 13 0.74 (0.40 to 1.39) |
| Abrasion/Bleeding/Burn/Blister | 0 0.00 (0.00 to 0.28) | 0 0.00 (0.00 to 0.23) | 2 0.11 (0.01 to 0.41) |
| Other | 3 0.18 (0.04 to 0.54) | 0 0.00 (0.00 to 0.23) | 2 0.11 (0.01 to 0.41) |
| Missing/Unknown‡ | 15 0.92 (0.53 to 1.60) | 19 1.19 (0.69 to 2.06) | 15 0.86 (0.51 to 1.44) |

*Crude rates with 95% exact Poisson CIs.†Sum of n is 1842, given that it is player-season (195 players participated in more than one season).‡Corresponding 95% Poisson CIs adjusted for cluster by team (offset by game-hours).BC, body checking.

Body checking experience compared with teams in Quebec with none). As such, their results may be confounded due to inter-provincial differences such as style of play or coaching tactics. Furthermore, the previous study was limited to the top 30% by division of play and with only 1 year follow-up, while the current study is strengthened by its examination across all levels of play and 5 years of longitudinal data.

Injury rates were significantly higher for players in the lowest weight category (<40 kg) relative to those weighing between 40 and 79 kg. This finding was inconsistent with previous U-15 ice hockey studies that found either no difference or an increased rate of injury in heavier players. Lighter players also had a non-significant 74% greater rate of concussion (IRR=1.74; 95% CI: 0.99 to 3.04); given the lower limit of the CI was 0.99, potentially a larger sample size may have yielded this significant. A previous U-13 study found lighter players had an increased rate of concussion. Differences in our findings with past U-15 studies may be due to different populations of interest and the different categorisations of weight. The present study categorised weight based on the log (rate) to ensure assumptions of linearity were not violated; a technique used in a previous youth ice hockey study.
Players with a previous history of injury or concussion had a higher rate of injury and concussion, respectively, which was consistent with previous studies. Goal-tenders had a lower injury and concussion rate in the present study, compared with forwards. This was also consistent with previous studies in both U-15 and U-13 age categories. Year of play was not identified to be a risk factor for injury. Previous studies have suggested first year players to be at greater risk of injury and concussion; however, the most recent findings at the U-15 age category also did not identify year of play as a significant risk factor.

**Limitations**

The classification of years of body checking experience as the primary exposure variable of interest does not take into consideration the number of body checks a player gives and receives. While all players in the present study participated in a league permitting body checking, future video-analysis studies could consider the number of body checks as a measure of experience. The outcomes of interest for this study (game-related injury and concussion) were based on game-related policy changes and did not consider practice-related injury or exposure data. All concussions were included if they met the study definition; however, it is noted that not all players with a suspected concussion followed up with a physician (51/64 saw a physician (79.7%) in those with no body checking experience, 53/61 (86.9%) in those with 1 year of body checking experience and 43/49 (87.8%) in those with 2+ years of body checking experience). Many factors may contribute to return to play decisions such as importance of the game, motivation, personality factors and parental influence. Each of these factors may have affected the precision of the IRR estimate for injury resulting in days of time-loss and concussion resulting in 10 days of time-loss. The return to play protocols established by the International Consensus Statement on Concussion in Sport were followed to support harmonisation of return to play between physicians and clinics. There is the potential for non-differential misclassification of concussion resulting in 10 days of time-loss if there was a delay of more than three days until the athlete could see a study physician and then progressed through the return to play protocol and changes in practice may have led to more conservative approaches over the study period; however, this would be similar regardless of body checking experience. While the 10-day time-loss cut-point for concussion was supported by previous consensus statements and allows for comparison with previous youth ice hockey studies, the 5th International Conference on Concussion in Sport suggests typical clinical recovery following concussion is within 1 month. Self-reported covariates on the PBQ may be subject to recall bias. Position of play may not have been consistent for every game during the season for each player as reported at baseline. Sex was not included as a covariate in the adjusted analyses due to very few females participating in primarily male, body checking divisions of play. Players who participated in ‘girls-only’ leagues where policy did not permit body checking in games were excluded from this study despite the potential for significant player-to-player contacts during game play. Future youth ice hockey studies examining ‘girls-only’ leagues are recommended. There may be the potential for selection bias based on teams’ unwillingness to participate in the cohort; however, the reason for non-participation was mainly due to the inability for identification of a team safety designate willing to volunteer to support injury surveillance throughout the playing season. It therefore seems unlikely that non-participation would be related to both body checking experience and subsequent injury outcomes. Socioeconomic status was not collected as part of the study, although the inclusive sampling strategy across city associations and study years should minimise any potential confounding effect. Selection bias may be of concern in that some players could have stopped playing hockey after sustaining a concussion leading to a loss to follow-up. The players that continue to participate (the ‘survivors’) would then have more body checking experience and may have lower rates of injury and concussion. More research is needed to better understand this effect.

**CONCLUSIONS**

We did not find that the rate of injury, injury resulting in >7 days of time-loss, concussion and concussion resulting in >10 days of time-loss was affected by body checking experience. This contradicts the notion that permitting body checking in U-13 age groups protects players from injury at the U-15 age category. Given the robust research suggesting that policy disallowing body checking is associated with lower injury and concussion rates specifically, this study adds to the literature in that there are no unintended injury consequences associated with such body checking policy decisions.

**Key messages**

- Research has informed body checking policy change disallowing body checking in games for multiple adolescent ice hockey leagues and divisions of play.
- Evaluations of these body checking policy changes demonstrate lower rates of injury and concussion in leagues prohibiting body checking.

**What is already known on this topic?**

- Risk of injury and concussion significantly increased for U-15 players (ages 13–14 years) that had no body checking experience and those that had either 1 year or 2+ years of body checking experience.

**What this study adds?**

- No significant differences were found in the rates of injury or concussion specifically among U-15 players (ages 13–14 years) that had no body checking experience and those that had either 1 year or 2+ years of body checking experience.
- Lighter players (<40 kg) had higher rates of injury than heavier players.
- Players with a 1 year previous injury history had higher rates of injury than players without a 1 year injury history.

**How this study might affect research, practice, or policy?**

- The greatest public health impact in reducing injuries and concussions may be seen through policy disallowing body checking, with no unintended injury consequences of fewer years of body checking experience for adolescent players participating in leagues allowing body checking.

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Contributors PE, BEH, LP-D, AMB and CE contributed to the study proposal development, PE, BEH, LP-D, VWWK, AMB and CE contributed to the data collection, entry and data cleaning. PE, BEH, LP-D, VWWK, SB and CE contributed to the data analysis and interpretation of study results. SB, MM and CL contributed to all aspects of data collection at study sites outside of Calgary. CE and BEH contributed to acquisition of funding, study design and led all aspects of the cohort. All authors critically reviewed and edited the manuscript before submission. CE is the study guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Hockey Canada, BC Hockey, Hockey Calgary, and Hockey Edmonton were involved as knowledge brokers in contributing to approval of study design, study recruitment, injury surveillance methods, support of safety designate role and dissemination of research findings within the hockey community. The research questions and outcome measures were developed and informed by the priorities, experience, and preferences of Hockey Canada, BC Hockey, Hockey Calgary and Hockey Edmonton. Hockey players, parents, coaches and administrators in Hockey Canada, BC Hockey, Hockey Calgary, Airdrie Minor Hockey, and Hockey Edmonton were dedicated to the collection of weekly exposure data, identification of a player with a suspected concussion, and supporting communication with the research team for injury follow-up. A knowledge broker from Hockey Canada and Hockey Calgary informed the methods and time commitment for study participation by players and parents and safety designates.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was received from the research ethics boards at the University of Calgary (Ethics ID: REB14-0348 and REB14-2209), University of Alberta (Ethics ID: REB Pro00024093) and the University of British Columbia (Ethics ID: CW14-0304/H14-01894). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

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