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# Concussion Burden, Recovery and Risk Factors in Elite Youth Ice Hockey Players

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Pre-publication

77 **Abstract:**

78

79 **Objective:** To examine rates of concussion and more severe concussion (time loss  
80 greater than 10 days) in elite 13-17 year old ice hockey players.

81

82 **Methods:** This is a prospective cohort study (Alberta, Canada). Bantam (13-14  
83 years) and Midget (15-17 years) male and female elite (top 20% by division of play)  
84 youth ice hockey players participated in this study. Players completed a  
85 demographic and medical history questionnaire and clinical test battery at the  
86 beginning of the season. A previously validated injury surveillance system was used  
87 to document exposure hours and injury during one season of play (8 months).  
88 Players with a suspected ice hockey-related concussion were referred to the study  
89 sport medicine physicians for assessment. Time loss from hockey participation was  
90 documented on an injury report form.

91

92 **Results:** Overall, 778 elite youth ice hockey players (659 males, 119 females; aged  
93 13-17 years) participated in this study. In total, 143 concussions were reported.  
94 The concussion incidence rate (IR) was 17.60 concussions/100 players (95% CI;  
95 15.09, 20.44). The concussion incidence rate (IR) was 1.31 concussions/1000  
96 player-hours (95% CI; 1.09, 1.57). Time loss greater than 10 days was reported in  
97 74% of cases (106/143) and 20% (n=28) had time loss of greater than 30 days.

98

99 **Conclusion:** Concussion is a common injury in elite youth ice hockey players. In  
100 this study population, a large proportion of concussions (74%) resulted in a time  
101 loss of greater than 10 days, possibly reflecting more conservative management or  
102 longer recovery in youth athletes.

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104 **Word count** = 244

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Pre-publication

118 **Introduction:**

119 Concussion is a brain injury.<sup>1</sup> Concussion is one of the most commonly occurring  
120 injuries in youth sport and recreation and the most frequently reported injury in  
121 youth ice hockey.<sup>2</sup> The majority of individuals recover from concussion in 10-14  
122 days.<sup>3</sup> However, in youth who present to the emergency department, up to 30%  
123 remain symptomatic one month following concussion.<sup>4 5</sup> Notably, this estimate  
124 includes concussion related to all causes and likely represents a more severe cohort,  
125 as not all individuals who sustain a sport-related concussion will present to the  
126 emergency department. Similarly, estimates for recovery times of individuals seen  
127 at specialty clinics will be greater than overall recovery rates, as only those  
128 individuals who have not recovered in the initial period following injury will present  
129 to these clinics. Therefore, concussion recovery should be evaluated prospectively in  
130 a community-based cohort to encompass the entire spectrum of injury severity and  
131 to account for population-specific characteristics.

132 Concussion incidence and recovery have been evaluated in collegiate populations,  
133 but less evidence is available for youth.<sup>6 7</sup> While the majority of young athletes  
134 recover and return to sport, some individuals are left with persisting symptoms that  
135 affect function and their ability to participate in sport and activities of daily living.<sup>4</sup>  
136 Identification of risk factors for concussion is imperative.

137 The majority of Canadians between 15 and 19 years of age report participating in  
138 sport.<sup>8</sup> Ice hockey is a popular sport, with over 250,000 Canadians ages 12-17 years  
139 participating in ice hockey.<sup>9</sup> The majority of participants are male.<sup>8 9</sup> Ice hockey is

140 classified as a collision sport, with body checking being allowed in many Canadian  
141 leagues.<sup>9</sup> Risk of concussion has been reported to be highest among individuals  
142 participating in collision sports (e.g., ice hockey, rugby, football).<sup>6 7 10 11</sup> In a meta-  
143 analysis, the rate of concussion in youth ice hockey are reportedly 1.20 (95% CI;  
144 1.00, 1.31) per 1000 athlete exposures.<sup>11</sup> This rate was second only to rugby in  
145 individuals under the age of 18 years.<sup>11</sup> Therefore, there is an inherent risk of injury  
146 associated with ice hockey participation, including the potential for long-term  
147 impairments and disability.

148 Historically, there has been concern regarding underreporting of concussion.<sup>12</sup>  
149 Thus, it is important to evaluate concussion rates in youth ice hockey prospectively  
150 using valid surveillance techniques, with particular attention to those with a longer-  
151 term recovery. The primary objective of this study is to evaluate the incidence rate  
152 of concussion and concussion with longer-term recovery in elite youth ice hockey  
153 players aged 13-17 years. Secondary objectives of this study were: 1) To evaluate  
154 risk factors for concussion and longer-term recovery (i.e., time loss of greater than  
155 ten days) in elite youth ice hockey players aged 13-17 years, to inform the  
156 optimization of prevention and intervention strategies; and 2) To determine if there  
157 was a difference in time to medical clearance to return to sport between males and  
158 females.

159 **Methods:**

160 This is a prospective cohort study completed during the 2011-2012 ice hockey  
161 season.

162 Participants:

163 **Male and female youth ice hockey teams were eligible for participation if they**  
164 **were in the top two levels of play (“AA” and “AAA”) and in the Bantam (13-14**  
165 **years of age) and Midget (15-17 years of age) age groups** in Calgary and  
166 Edmonton, Canada. These teams represented the most elite 20% of players in the  
167 eligible age groups. The male players in this study played in leagues that allowed  
168 body checking, whereas the female leagues did not allow body checking. **Players**  
169 **who had sustained an injury or had a chronic illness that prevented full**  
170 **participation in ice hockey prior to the beginning of the season were excluded.**

171 Hockey associations were informed of the study objectives and once the  
172 associations' permission had been granted, their team coaches and therapists were  
173 approached for recruitment. Following coach consent, individual players and  
174 parents were invited to participate. Both parental consent and player assent were  
175 obtained prior to participation. This study was approved by the Conjoint Health  
176 Research Ethics Board at the University of Calgary, Calgary, Alberta, Canada (Ethics  
177 ID 24026) and the University of Alberta, Edmonton, Alberta, Canada (Ethics ID  
178 00003490).

179 **Procedures:**

180 Baseline questionnaires, including demographic, medical, and injury history  
181 (including reports of previous concussion), were collected upon study entry. Each  
182 participant then completed a baseline testing session that included evaluation of a  
183 variety of test domains. Baseline measures included the Sport Concussion



184 Assessment Tool 2 (SCAT2), Immediate Post-Concussion Assessment and Cognitive  
185 Test (ImPACT) and Behaviour Assessment System for Children, Second Edition  
186 (BASC-2). A battery of clinical cervical and vestibular measures and a computerized  
187 test of dynamic visual acuity were also administered in the Calgary cohort. Detailed  
188 characteristics of these measures are reported elsewhere, as the focus of this paper  
189 is concussion burden, risk factors, and recovery in elite youth ice hockey players.

190  
191 A previously validated injury surveillance system was used to prospectively collect  
192 exposure and injury data throughout the 2011-2012 playing season.<sup>13</sup> Each  
193 participating team had a team therapist who collected weekly exposure information.  
194 This included data regarding games, dryland training, and practices. Missing  
195 individual exposure data were imputed based on mean team exposure values. In the  
196 case of missing team data, exposure was imputed based on mean age group and sex  
197 specific exposure values. Previous evaluation of weekly exposure imputation  
198 techniques has identified this as an appropriate and valid method.<sup>14</sup> Team  
199 therapists also collected concussion data using standardized injury report forms  
200 (IRF).

#### 202 Concussion:

203 At the time of a suspected concussion (based on team therapist assessment or  
204 athlete/parent referral) participants were referred to a study sport medicine  
205 physician for follow-up. Concussions were diagnosed according to the definition and  
206 recommendations of the consensus statement on concussion in sport.<sup>15</sup> Each

207 concussion was individually medically managed as indicated by clinical assessment  
208 findings and according to the standard of care, including an initial period of rest  
209 followed by a standardized protocol of exertion prior to medical clearance to return  
210 to play.<sup>15</sup>

211

212 Time loss was determined as the number of days to medical clearance to return to  
213 sport. Clinical follow-up data (e.g., medical charts) were the most accurate measure  
214 of medical clearance to return to play and provided the primary source of time loss  
215 information. A study physiotherapist was in continual communication with injured  
216 participants to ensure that follow-up visits with study physicians were completed at  
217 the time point of completion of the return to play protocol. In the event that an  
218 individual failed to return for their final follow-up visit and had not yet initiated the  
219 return to play protocol, seven days were added to the last date of follow-up, as a  
220 reflection of the earliest possible date of return to play as per the **return to play**  
221 protocol (McCrary et al).<sup>15</sup> In the event that the season ended and no further follow-  
222 up was available, the final date from the weekly exposure form was used as the final  
223 date of time loss.

224 Evaluation of Risk Factors for Concussion:

225 Previous history of concussion was defined based on a self-reported “yes” or “no”  
226 answer to the question: “Have you ever had a concussion or been ‘knocked out’ or  
227 ‘had your bell rung?’” on the preseason baseline questionnaire. Additional risk  
228 factors included self-reported sex (male/female), height, weight, year of play  
229 (1<sup>st</sup>/2<sup>nd</sup> year of play in Bantam; 1<sup>st</sup>/2<sup>nd</sup>/3<sup>rd</sup> year of play in Midget), position of play

230 (forward, defense, goalie), injury in the year prior to the season, and family history  
231 of headache. The number of symptoms at baseline, symptom severity score,  
232 Standardized Assessment of Concussion score (SAC) and Balance Examination Score  
233 (BES) were also evaluated as risk factors for concussion.

234

235 Analyses:

236 Baseline characteristics were summarized (proportions for categorical data,  
237 medians and Interquartile ranges (IQR) for numerical data). The primary objectives  
238 were assessed using crude injury rates (calculated as the number of  
239 concussions/100 players) and rates for concussion and concussion with time loss of  
240 greater than 10 days (number of concussions/1000 player-hours). A univariate  
241 Poisson regression analysis was conducted to highlight potential risk factors (sex,  
242 age group, previous concussion, height, weight, symptoms, previous injury, position,  
243 year of play, Sport Concussion Assessment Tool Scores). Poisson regression analysis  
244 using backward elimination, including adjustment for clustering by team and offset  
245 for exposure hours of participation was used to evaluate rates of concussion and  
246 rates of concussion with time loss of greater than 10 days between males and  
247 females **while adjusting** for covariates of previous history of concussion and age  
248 group. Time from medical clearance to return to sport, by sex, for first concussion  
249 was evaluated using a Kaplan-Meier curve.

250

251 **Results:**

252 **Fifty-four teams were approached to participate and 44 teams agreed to**  
253 **participate. An inclusive sample of 854 players who were playing on these**  
254 **teams were approached to participate. (See Figure 1)** A total of 778 elite ice  
255 hockey players ages 13-17 years (N=44 teams; 31 in Calgary and 13 in Edmonton)  
256 participated in this study. Most participants were male (n=659, 84%), with 119  
257 female players (16%) included in the cohort. Participants included 241 (31%)  
258 Bantam players (13-14 years of age) and 537 (69%) Midget players (15-17 years of  
259 age). Eight players who were on one of the study teams at baseline were  
260 subsequently cut from the roster and played on a lower level team. As these  
261 individuals could be called up during the season to play on a participating team, they  
262 remained in the study. It was assumed that their exposure would be similar to the  
263 players on the team from which they were cut, so this was imputed based on mean  
264 team exposure hours for these players.

265 Insert Figure 1

266

267 Baseline demographic information for all participants is outlined in Table 1. A  
268 previous history of concussion was reported by 39.1% (n=304) of the sample, with  
269 249 players (32.0%) reporting one previous concussion, 48 players (6.2%)  
270 reporting two previous concussions, six players reporting three previous  
271 concussions (0.8%) and one individual reporting four previous concussions (0.1%).  
272 Of those reporting previous concussions, four (1.3%) reported ongoing difficulties  
273 with memory, 16 (5.3%) reported ongoing difficulties with dizziness and 43  
274 (14.1%) reported ongoing persisting headaches attributed to their past concussions.

275

276 Insert Table 1

277

278 Concussions rates by sex

279 A total of 143 concussions occurred during the season of play. One hundred and  
280 thirty-one players sustained one concussion and six players sustained two  
281 concussions. After adjusting for cluster by team, the concussion incidence rate was  
282 17.60 (95% CI; 15.09, 20.44) concussions per 100 players. The concussion incidence  
283 rate was 1.31 (95% CI; 1.09, 1.57) concussions per 1000 player hours. Rates of  
284 concussion in males and females were not found to be **significantly** different in this  
285 study (Table 2).

286

287 Insert Table 2

288

289 Risk factors for concussion and for longer recovery

290 *Unadjusted Univariate analysis*

291 The following output relates to estimates on a univariate level, adjusting only for  
292 cluster by team and offsetting for exposure hours. The rate of concussion was not  
293 significantly different between males and females ( $IRR_{\text{Concussion}}=0.95$ ; 95% CI 0.71-  
294 1.25 and  $IRR_{\text{Timeloss}>10\text{days}} = 0.99$ ; 95% CI; 0.61, 1.62) or between Bantam and Midget  
295 players ( $IRR_{\text{Concussion}}=0.96$ , 95%CI: 0.66-1.40 and  $IRR_{\text{Timeloss}>10\text{days}} = 0.86$ ; 95% CI  
296 0.57-1.27). Individuals who reported an injury in the year prior to the season had a  
297 1.51 (95% CI; 1.06, 2.17) times higher rate of concussion with a time loss of greater

298 than 10 days compared to individuals who did not report an injury in the year prior  
299 to the season. Individuals reporting a greater number of symptoms at baseline  
300 (SCAT2) had, **on average**, a greater rate of concussion and concussion with > 10 day  
301 time loss [IRR=1.05 (95% CI; 1.01, 1.10) and 1.07 (95% CI; 1.03, 1.12) respectively].  
302 Individuals with a greater symptom severity score at baseline (SCAT2) had a higher  
303 rate of concussion [IRR=1.03 (95% CI; 1.01, 1.04)] and concussion with > 10 day  
304 time loss during the season of play [IRR=1.03 (95% CI; 1.01, 1.05)] (Table 3).

305

306 Insert Table 3

307

308 Sex as a risk factor for concussion:

309 *Multiple variable analysis*

310 An exploratory multiple variable Poisson regression analysis including adjustment  
311 for age group, previous history of concussion, and adjusted for clustering by team  
312 and offset for exposure hours was used to evaluate sex as a risk factor for  
313 concussion. Based on this multiple variable analysis, there was no significant  
314 difference in concussion rate between males and females [IRR=1.01 (95% CI; 0.76,  
315 1.34) p=0.93] or concussion with time loss of greater than 10 days [IRR=1.08 (95%  
316 CI; 0.67, 1.75)].

317

318 Recovery from concussion:

319 The median time loss from concussion was 17 days (0-120) for the first concussion  
320 and 10 days (7-130) for the second concussion (n=6). Thirty-seven of all

321 concussions (26%) had a time loss of 10 days or less. Seventy four percent (n=106)  
322 of all concussions had a time loss of > 10 days, with 20% (n=28) having a time loss  
323 of greater than 30 days. Three players sustained two concussions with a time loss of  
324 greater than 10 days and 100 players sustained one concussion with a time loss  
325 greater than 10 days. Two players had a concussion with a time loss of greater than  
326 90 days (Table 4 and Figure 1). The survival curves examining time to clearance to  
327 return to play for males and females crossed at several time points. As such we can't  
328 conclude that there is a difference between males and females in time to recovery  
329 and we were unable to perform a Log Rank to evaluate a difference.(Figure 1) For  
330 five concussions (3.5%), time loss was estimated based on the last date of follow-up  
331 plus seven days to represent the earliest possible date of return to activity. For two  
332 concussions (1.4%) that had not resolved by the end of the season, time loss was  
333 recorded as the last date indicated on the weekly exposure form.

334

335 Insert Table 4

336 Insert Figure 2

337 **Discussion:**

338 This study included 778 elite youth ice hockey players (84.7% male), all of whom  
339 were playing in the most elite divisions in their age group. The concussion incidence  
340 rate [IR=1.31 concussions per 1000 players hours (95% CI; 1.09, 1.57)] observed in  
341 this cohort was higher than that previously reported for the same league (IR=0.79;  
342 95% CI 0.55-1.31 concussions/1,000 player hours),<sup>16</sup> but the previous estimate

343 included all levels of play. However, the rate of concussion with time loss of >10  
344 days [1.08 (95% CI; 0.67, 1.75) concussions/1000 player hours in adolescent males]  
345 was higher than the previously reported rate of 0.28 (95% CI; 0.15-0.53)  
346 concussions/1000 player hours.<sup>17</sup> This higher rate may be reflective of more  
347 conservative medical clearance decisions pertaining to return to play, as per recent  
348 consensus guidelines.<sup>3</sup>

349 Of interest, the overall rate of concussion and concussion resulting in time loss of >  
350 10 days were not found to be different in male and female players, despite rules  
351 prohibiting body checking in the female leagues. In collegiate athletes, a similar risk  
352 of concussion was also observed in male (body checking) and female (non-body  
353 checking) leagues over multiple years of participation [7.91 (95% CI, 6.87-8.95) and  
354 7.50 concussions (95% CI, 5.91-9.10) per 10,000 athlete exposures respectively].<sup>6</sup>  
355 Body checking is consistently reported as the primary mechanism of injury in ice  
356 hockey, and there is substantial literature demonstrating up to a four-fold greater  
357 risk of concussion associated with participation in body checking leagues.<sup>17 18</sup> It  
358 could, therefore, be hypothesized that women's leagues, which allow body contact  
359 but not body checking, would confer a protective effect. The similar incidence rate  
360 between males and females suggests that either females may be more susceptible to  
361 concussions from the lesser forces associated with body contact, or that there are  
362 distinct mechanisms of injury between male and female leagues. Alternatively,  
363 females may be more likely to report concussions, which is supported by findings of  
364 increasing concussion incidence over the years in women's ice hockey as compared  
365 to men's.<sup>17 18</sup> Further study is clearly warranted to better understand the risk of



366 concussion and mechanisms by which these injuries occur. Studies employing  
367 methodologies such as video analysis and biomechanical modeling may provide  
368 insight into potential sex differences.

369 In the present study, 80% of players were medically cleared to return to play within  
370 30 days of injury. This is similar to recent estimates of recovery in youth and high  
371 school football.<sup>19</sup> However, in 2011, Meehan et al. found that only 2.8% of high  
372 school athletes reported concussion symptoms for greater than one month  
373 following injury.<sup>20</sup> Mean times to recovery in collegiate male and female ice hockey  
374 players have also been reported to be lower, varying between 6.67 and 9.96 days in  
375 the 2004-2009 seasons.<sup>21</sup> Female middle school soccer players who have suffered a  
376 concussion have been reported to have a median symptom duration of only 4.0  
377 days.<sup>22</sup> It may be that a greater awareness of concussion and more cautious  
378 management has been undertaken in recent years, resulting in a longer time loss  
379 from play in more recent studies. For example, better adherence to a graduated  
380 return to play protocol would result in longer time to recovery because individuals  
381 would take a minimum of 24 hours to progress through each of the six steps of  
382 graded exertion recommended by current best practice guidelines.<sup>3</sup>

383 Limitations:

384 This study employed a previously validated prospective injury surveillance system,  
385 but it is possible that some concussions were unreported. Yet, as each team had a  
386 therapist monitoring for concussions and the reported incidence was high, we  
387 expect that this potential underreporting was minimized. If there were concussions

388 that went unreported, the true incidence of concussion may be underestimated in  
389 this study.

390 Individuals reporting a greater number and intensity of symptoms at baseline were  
391 at an increased risk of concussion. It may be that individuals who are more likely to  
392 report symptoms are also more likely to report concussions, thus potentially  
393 overestimating the association between the presence of symptoms and risk of  
394 concussion. **A previously validated injury surveillance system was**  
395 **implemented. However, it is possible that some of the risk factors of interest**  
396 **may have varied over time (e.g. position of play, subcomponent scores from**  
397 **the SCAT).**

#### 398 **Conclusions:**

399 Concussion is a common injury in elite youth ice hockey players ages 13-17 years.  
400 **Time loss greater than 10 days was reported in 74% of cases (106/143) and**  
401 **20% (n=28) had time loss of greater than 30 days.** The concussion rate did not  
402 differ between male and female players, despite rule differences allowing body  
403 checking in male leagues. Players with a previous history of concussion, greater  
404 number of baseline symptoms, and greater intensity of symptoms at baseline were  
405 at an increased risk of concussion. Future research examining potential differences  
406 in mechanism of concussion injury between males and females is recommended.  
407 The high rate of concussion reported in this study speaks to the need for future  
408 work to identify prevention strategies for concussion in youth athletes.

409

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Pre-publication

494 **Figure Legend:**

495 Figure 1. Summary of team and player recruitment

496 Figure 2. Kaplan Meier curve for time to medical clearance in males and females

Pre-publication