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1 **Higher Rates of Head Contacts, Body Checking, and Suspected Injuries in Ringette than**
2 **Female Ice Hockey: Time to Ring in Opportunities for Prevention**

3
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47 **Abstract**

48 **Objective:** Ringette and female ice hockey are high participation sports in Canada. Despite
49 policies disallowing body checking, both sports have high injury and concussion rates. This
50 study aimed to compare physical contact (PC), head contact (HC), and suspected injury and
51 concussion incidence rates (IR) in female varsity ringette and ice hockey.

52 **Design:** Cross-sectional.

53 **Setting:** Canadian ice arenas.

54 **Participants:** Eighteen Canadian female university ringette and ice hockey tournament/playoff
55 games in the 2018-2019/2019-2020 seasons.

56 **Assessment of Risk Factors:** Game video-recordings were analyzed using Dartfish video-
57 analysis software to compare both sports.

58 **Main Outcome Measures:** Univariate Poisson regression analyses (adjusted for cluster by team,
59 offset by game-minutes) were used to estimate PC, HC, and suspected injury IRs and incidence
60 rate ratios (IRRs) to compare rates across sports. Proportions of body checks (level 4-5 trunk PC)
61 and direct HC (HC₁) penalized were reported.

62 **Results:** Analyses of 36 team-games (n=18 ringette, n=18 hockey) revealed a 19% lower rate of
63 PCs in ringette than ice hockey [IRR=0.81 (95%CI:0.73-0.90)], but a 98% higher rate of body
64 checking [IRR=1.98 (95%CI:1.27-3.09)] compared to ice hockey. Ringette had a 40% higher
65 rate of all HC₁s [IRR=1.40 (95%CI:1.00-1.96)] and a 3-fold higher rate of suspected injury
66 [IRR=3.11 (95%CI:1.13-8.60)] than ice hockey. The proportion of penalized body checks and
67 HC₁s were low across sports.

68 **Conclusions:** Body checking and HC₁ rates were significantly higher in ringette compared to ice
69 hockey, despite rules disallowing both, and very few were penalized. These findings will inform
70 future injury prevention research in ringette and female ice hockey.

71 **Key words:** ringette, ice hockey, athletic injury, concussion, female, video analysis

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92 **INTRODUCTION**

93 Ringette and female ice hockey are high participation female ice team sports with over 32,000
94 ringette and 101,000 female ice hockey players participating in Canada in the 2019-2020 season.^{1,2}

95 In Canada, participation in ringette and female ice hockey have increased since the early 2000s.^{1,2}

96 Unfortunately, both female ice sports are associated with a high risk of injury, including
97 concussion.^{3,4} Body checking (i.e., intentional forceful contact to stop an attack or separate the

98 opponent from the puck/ring⁵) is prohibited in both ringette and female ice hockey, however

99 previous research demonstrates that contact with another player (either intentional or
100 unintentional) is the primary mechanism of injury.^{6,7}

101

102 In a study investigating the epidemiology of sport-related injuries reporting to Canadian

103 emergency departments, female ringette and ice hockey players had the highest proportion of

104 sport-related injuries diagnosed as concussions (17.1% and 13.3% respectively).³ Further, a cross-

105 sectional survey among high school students (ages 14-19) reported that ringette had the highest

106 concussions rate (19.05 concussions/100 students/year) compared to all other youth sports,

107 including male ice hockey (17.20 concussions/100 students/year).⁴ In a one-season cohort study

108 among collegiate ice hockey players, injury rates among female (7.77 injuries/1000 athletic

109 exposures [AE]) and male (9.19 injuries/1000 AEs) players were similar (relative risk = 1.18, p =

110 0.258, 95% CI: 0.89-1.57) and concussions were the most common injury in females (thigh injury

111 was the most common injury in males).⁸ Moreover, concussions resulted in the greatest burden of

112 injury (e.g., longer recovery, more severe symptoms), resulting in the greatest time loss compared

113 to other injury types in both sexes. Specific to female varsity ice hockey, a different study reported

114 a concussion rate of 1.18 concussions/1000 AEs.⁹ In another female youth ice hockey study, the

115 overall injury rate reported was 1.9 injuries/1000 player-hours (including concussions) or 16.3
116 injuries/100 players/season.⁶ To our knowledge, there is no current injury epidemiology literature
117 in ringette that includes player exposure.

118

119 A noteworthy difference between male and female ice hockey is that body checking is not allowed
120 in female ice hockey, whereas elite levels of male ice hockey allow body checking in 13-17-year-
121 old leagues. This difference has resulted in the common belief that female ice hockey is a safer
122 sport, with a lower perceived risk of injury.¹⁰ This may explain the lack of research investigating
123 injuries in female compared to male ice hockey. In the few studies that do include female ice
124 hockey, the majority combine male and female into the same sample, where females make up a
125 significantly smaller amount of that sample.¹⁰ Previous research has shown that the injury profile
126 of female ice hockey players differs from male ice hockey players.¹¹

127

128 Despite the high risk of injury, specifically concussion, among ringette and female ice hockey
129 players, there is a paucity of injury epidemiology research in this population. Further investigation
130 into injury burden, risk factors, and mechanisms in ringette and female ice hockey is needed to
131 inform injury prevention programs and strategies. It is crucial to assess the concussion and injury
132 risk specific to ringette and female ice hockey players. This study aimed to compare physical
133 contact (PC) and head contact (HC) incidence rates (IR), and suspected injury and concussion rates
134 in female varsity ringette and ice hockey using video analysis. Previous research has demonstrated
135 that video analysis is an effective tool to assess injury situations in various high injury risk team
136 sports.¹²⁻¹⁴

137

138 **METHODS**

139 **Design and Participants**

140 This is a cross-sectional video-analysis study based on 18 University level ringette and female ice
141 hockey games (games = 40 minutes for ringette and 60 minutes for ice hockey). Participants
142 included Canadian University level ringette players participating in the University Challenge Cup
143 tournament (n=18 team-games; N=9 games) and varsity female ice hockey players participating
144 in the Canada West playoff games (n=18 team-games; N=9 games) in the 2018-2019 and 2019-
145 2020 seasons. Ethical approval for this study was obtained from the University of Calgary
146 Conjoint Health Research Ethics Board (CHREB) (Ethics ID: REB21-0968).

147 **Video Footage Collection**

148 Video footage was previously collected during the 2018-2019 and 2019-2020 seasons and shared
149 with the study team via shared video viewing platforms: Periscope (ringette) and VidSwap (female
150 ice hockey). Permissions for the video footage to be analyzed anonymously (i.e., no linkage to
151 individual personal data) were granted by the Canadian University and College Ringette
152 Association (CUCRA) Registrar and the University of Calgary's interim director of Dino's
153 athletics for ringette and female ice hockey, respectively. Following permissions to access the
154 videos, the videos were downloaded from the viewing platforms onto a secure server (SharePoint).
155 Games were matched between sports based on game type (i.e., quarter final, semi final, final).
156 Games with poor video quality or camera angle were excluded (approximately 30% of games
157 excluded).

158 **Outcome Measures**

159 Games were analyzed for player-to-player physical contacts (PC) using previously validated
160 criterion¹⁵ on Dartfish Version 10.0 video-analysis software.¹⁶ Dartfish allows for videos to be

161 analyzed frame-by-frame using a custom-made tagging panel. Video analyzers included those with
162 a background (e.g., player or coach) in their respective sports (n=2 ringette; n=3 ice hockey). Video
163 analyzers were trained and achieved an inter-rater reliability ($\geq 90\%$) with a gold standard assessor
164 (R.W.) on the physical contact metrics including: contact mechanisms (i.e., trunk, limb, or stick),
165 trunk contact intensity (levels 1-5), and additional contact characteristics (e.g., location on ice,
166 intentional/unintentional, contact made with puck/ring carrier). This gold standard assessor has
167 extensive experience with 65+ games analyzed (i.e., 500+ hours of analysis) in team ice sports.

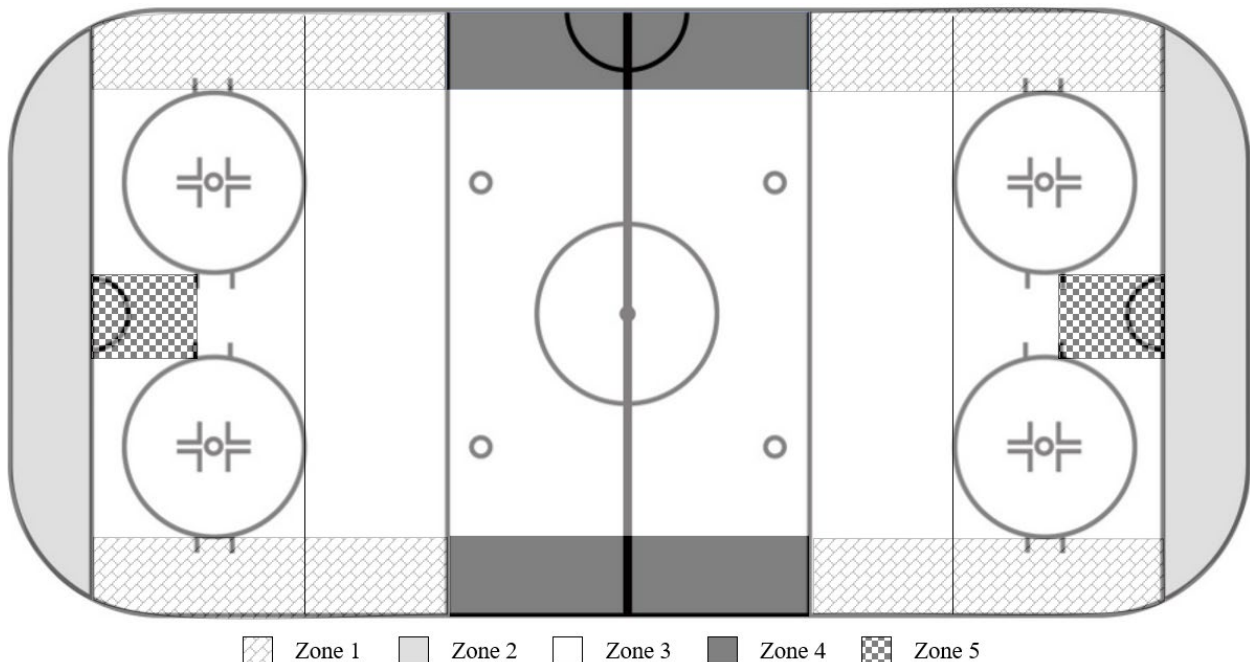
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169 Validated player-to-player PC metrics included trunk contacts classified by severity into 5 levels
170 (Table 1) where levels 1-3 were classified as body contact and levels 4-5 were considered body
171 checking.¹⁵ Other contacts included contacts made with the limbs or stick (e.g., pushing, hitting,
172 holding, hooking). Each PC was tagged with the contact zone on the ice (Figure 1), directionality
173 of the player giving the contact (offensive or defensive), intention of the contact (deliberate or non-
174 deliberate), if the contact was on the puck/ring carrier, and if a penalty was assessed by the referee.
175 Of the PCs recorded, all head contacts (HC) were examined further as a subset, whereby HC were
176 classified as either primary/direct contact by opposing players (HC₁) or secondary/indirect contact
177 to the head after a collision via the boards, glass, or ice surface (HC₂). Suspected non-concussion
178 injuries were assessed based on criteria from previous video analysis from professional soccer.¹⁷
179 Criteria included: referee stopped play for injury, player remained on the ice for longer than 15
180 seconds after contact, and the player appeared to be in pain. Suspected concussions were assessed
181 using 17 previously used video signs of concussion from professional sport based on expert
182 consensus (e.g., lying motionless, dazed, slow to get up, clutching at head).¹⁸ Suspected injuries,

183 including concussion, were included in the analysis if they met one or more criteria from the
 184 aforementioned video analysis studies.

185 **Table 1.** Trunk and other physical contact definitions based on Malenfant et al. (2012).¹⁵

		Definition
Trunk physical contact (PC)		
Level 1		Very light contact between two stationary players
Level 2		Light contact between two players moving in the same relative direction
Level 3		Moderate contact between two players moving in the same relative direction
Level 4		Heavy contact, with one player forcefully exerting one's body into the opposing player, usually moving in the opposite direction. Minimum requirement of a body check
Level 5		Excessive, deliberate contact from one player with the intention beyond impeding the progress of the opponent, moving in the opposite direction
Other physical contact (PC)		
Limb		Contact using one or both upper extremities, such as pushing, punching, or holding
Stick		Contact to the body using the stick, such as slashing or hooking

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189 **Figure 1.** Zones of the ice hockey/ringette arena adapted from Malenfant et al. (2012).¹⁵

190

191 **Data Analysis**

192 All data was analyzed using STATA version 15.1 statistical software.¹⁹ Incidence rates (IR) were
193 expressed as the number of contacts per 100 team-minutes. Incidence rate ratios (IRR) were used
194 to compare rates between sports using univariate Poisson regression analyses adjusted for cluster
195 by team and offset by game length (in minutes). IRs and frequencies were used to describe PC
196 behaviours including PC mechanisms and characteristics.

197 **RESULTS**

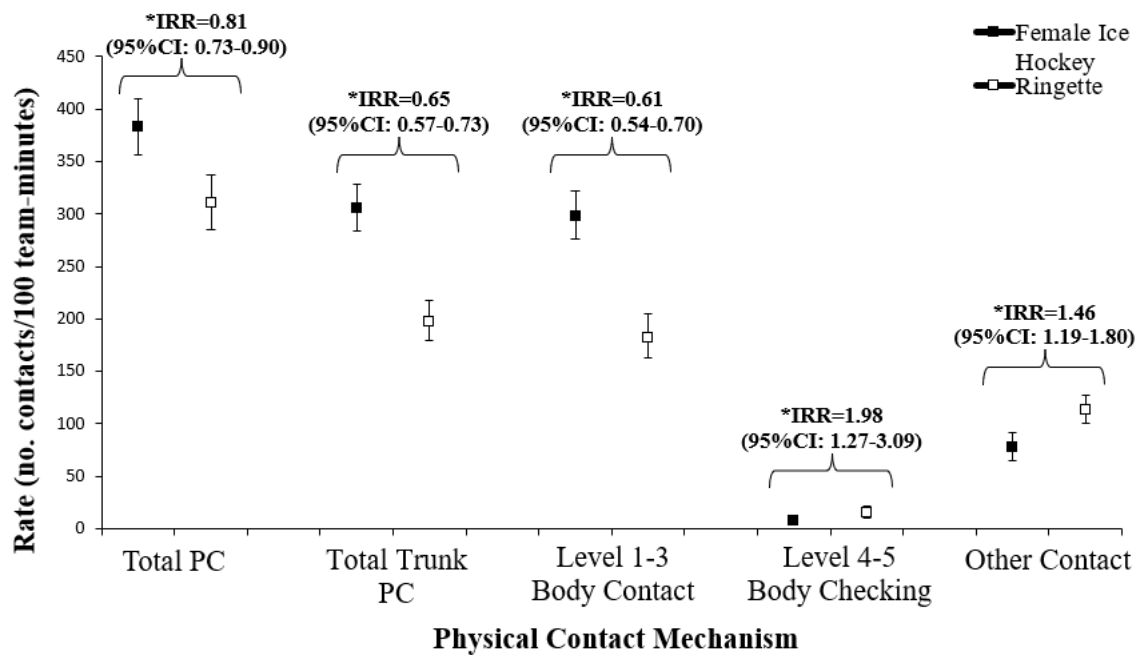
198 **Game Selection**

199 A total of 9 games or 18 team-games were analyzed in ringette and female ice hockey. Four
200 round robin/quarter-final games were selected from each season (2018-2019 and 2019-2020) as
201 well as one final game from the 2019 season in both ringette and female ice hockey. Five ringette
202 games were excluded due to poor quality/angle of video where analysis could not be accurately
203 completed. No female ice hockey games were excluded due to poor quality/angle of video, but
204 ice hockey games were instead chosen to match ringette on game type (round robin and finals)
205 and season (2018-2019 and 2019-2020 seasons).

206 **Physical Contact Incidence Rates and Mechanisms**

207 In total, 2133 PCs in 686.3 ringette team-minutes and 4085 PCs in 1068.3 female ice hockey
208 team-minutes were analyzed. Overall, ringette had a 19% lower rate of total PCs (levels 1-5
209 trunk contacts and other contacts) than ice hockey (IRR=0.81, 95% CI: 0.73-0.90) (Figure 2).
210 Ringette also had a lower rate of total trunk (levels 1-5) PCs (IRR=0.65, 95% CI: 0.57-0.73) and
211 body contact PCs (levels 1-3 intensities; IRR=0.61, 95% CI: 0.54-0.70) compared to ice hockey

212 (Figure 2). However, ringette had a higher rate of body checking PCs (levels 4-5 intensities;
 213 IRR=1.98, 95% CI: 1.27-3.09) and other non-trunk PCs (IRR=1.46, 95% CI: 1.19-1.80)
 214 compared to ice hockey (Figure 2). Ringette and female ice hockey had high rates of intentional
 215 contacts compared to unintentional (95% for ringette and 97% for hockey) as well as contact
 216 made with the puck/ring carrier compared to a non-puck/ring carrier (92% for ringette and 73%
 217 for hockey). Incidence rates of all PCs including trunk and other contacts were analyzed (Table
 218 2) as well as the frequency of all PCs by each ice surface zone (Figure 3). When considering
 219 higher intensity body checks (level 4-5 intensities), the proportion of body checks penalized were
 220 low in ringette (22%) and ice hockey (15%), despite policy disallowing body checking in both
 221 sports.



222

223 **Figure 2.** Comparison of incidence rates for total physical contacts (PC), total trunk, body
 224 contact (level 1-3 intensities), body checking (level 4-5 intensities) and other (stick or limb
 225 inflicted) in-game physical contacts in ringette and female ice hockey using incidence rate ratios
 226 (IRR) adjusted for cluster by team and offset by game length.

227 Notes. *Statistically significant, 95% CI (confidence interval).

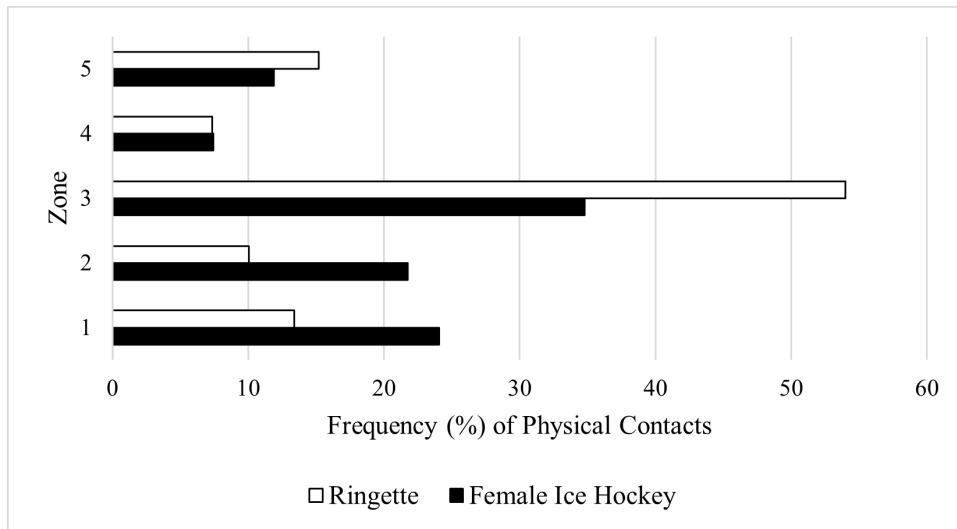
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229 **Table 2.** Incidence rates of all player-to-player physical contacts (PC) including trunk contact
 230 intensities and other contact types.

	Ringette	Ice Hockey
	PC Incidence Rate per 100 Team-Minutes (95% CI)	
Total PC	310.4 (285.4-337.5)	382.5 (356.8-410.0)
Trunk Contact	197.59 (179.09-218.01)	305.44 (283.92-328.58)
Total Levels 1-3	182.58 (162.89-204.66)	297.86 (275.81-321.66)
Level 1	46.0 (36.2-58.6)	109.8 (96.6-124.4)
Level 2	101.4 (86.5-118.9)	145.5 (132.4-159.8)
Level 3	35.1 (27.8-44.4)	42.6 (37.5-48.4)
Total Levels 4-5	15.01 (10.45-21.56)	7.58 (5.80-9.92)
Level 4	14.1 (9.6-20.8)	6.8 (5.3-8.8)
Level 5	0.9 (0.5-1.7)	0.7 (0.3-1.7)
Other Contact & Other Contact Type	112.79 (100.07-127.12)	77.04 (64.73-91.68)
Limb hit	5.5 (3.7-8.3)	3.4 (2.0-5.7)
Holding	1.2 (0.5-2.8)	3.0 (2.1-4.2)
Limb push	52.3 (44.7-61.2)	36.3 (27.4-48.2)
Slashing	35.1 (30.2-40.9)	12.4 (9.5-16.3)
Hooking	15.3 (11.3-20.7)	3.8 (2.6-5.7)
Cross checking	3.2 (1.6-6.4)	15.4 (9.8-24.3)

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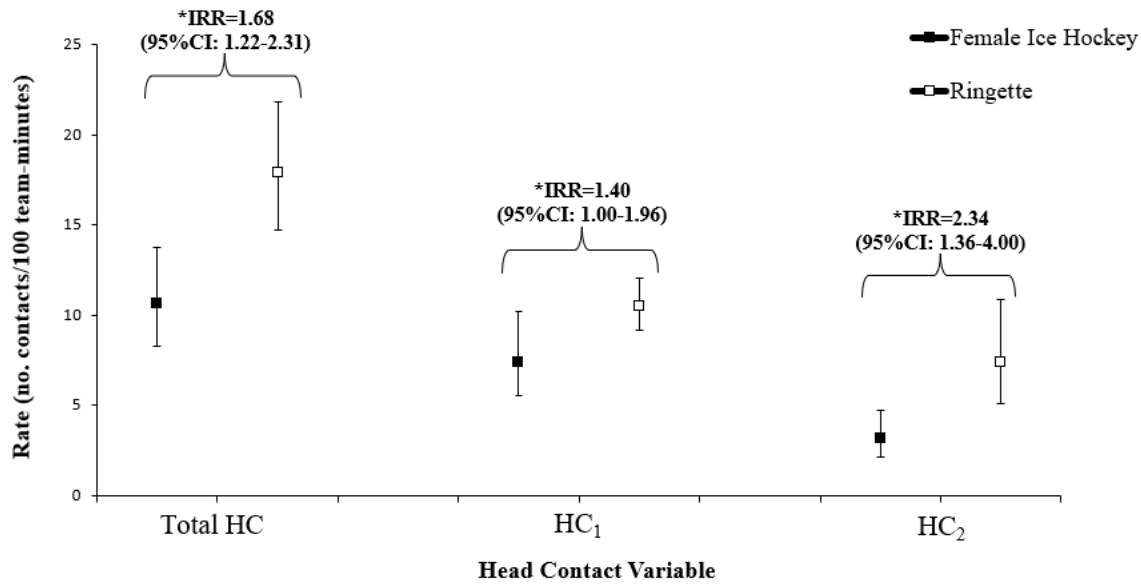


233 **Figure 3.** Frequency of all player-to-player physical contacts by each ice surface zone for both
 234 ringette and female ice hockey.
 235
 236

237 Head Contact Incidence Rates and Mechanisms

238 In total, 116 HCs in 686.3 ringette team-minutes and 111 HCs in 1068.3 female ice hockey team-
 239 minutes and were analyzed. Overall, ringette had a 68% higher rate of total HCs (IR=17.92
 240 HCs/100 team-minutes, 95% CI: 14.71-21.83) compared to ice hockey (IR=10.67 HCs/100
 241 team-minutes, 95% CI: 8.28-13.75) (IRR=1.68, 95% CI; 1.22-2.31) (Figure 4). The point-
 242 estimate showed a higher rate of HC₁ in ringette (IR=10.49 HC₁s/100 team-minutes, 95% CI:
 243 9.14-12.04) compared to ice hockey (IR=7.49 HC₁s/100 team-minutes, 95% CI: 5.50-10.20)
 244 (IRR=1.40, 95% CI: 1.00¹-1.96). Ringette also had a significantly higher rate of HC₂ (IR=7.43
 245 HC₂s/100 team-minutes, 95% CI: 5.08-10.86) compared to ice hockey (IR=3.18 HC₂s/100 team-
 246 minutes, 95% CI: 2.15-4.72) (IRR=2.34, 95% CI: 1.36-4.00). In ringette, 14% of all HC₁s were
 247 penalized and 5% of all HC₁s were penalized in ice hockey, despite HC₁s not being allowed in
 248 either sport. HC frequency by trunk contact intensities as well as other contact types were
 249 analyzed (Table 3).

¹ *95% CI deemed significant based on (95% CI: 1.004-1.956) before rounding.



250
 251 **Figure 4.** Comparison of incidence rates for total head contacts (HC), direct (HC₁), and indirect
 252 (HC₂) in-game head contacts in ringette and female ice hockey using incidence rate ratios (IRR)
 253 adjusted for cluster by team and offset by game length.
 254 Notes. *Statistically significant, 95% CI (confidence interval)
 255

256 **Table 3.** Incidence rates of all Head Contacts (HC) by intensities and other contact types.

	Ringette		Ice Hockey	
	HC Incidence Rate per 100 Team-Minutes (95% CI)			
	HC ₁	HC ₂	HC ₁	HC ₂
Level 1-3	6.4 (4.9-8.5)	2.2 (1.4-3.5)	4.6 (2.9-7.2)	1.6 (1.0-2.5)
Level 4-5	3.5 (2.6-4.7)	2.5 (1.1-5.6)	0.9 (0.4-2.1)	0.6 (0.2-1.3)
Object	0.1 (0.0-1.0)	1.2 (0.6-2.4)	0.6 (0.2-1.4)	0.3 (0.1-0.8)
Limb	0.4 (0.2-1.3)	0.4 (0.2-1.3)	1.4 (0.9-2.2)	0.5 (0.2-1.0)

257
 258 **Suspected Injuries and Concussions**
 259 Ringette had a 3-fold higher rate of suspected injury (IR=1.46 suspected injuries/100 team-
 260 minutes, 95% CI: 0.72-2.93) compared to ice hockey (IR=0.47 suspected injuries/100 team-
 261 minutes, 95% CI: 0.22-1.00) (IRR=3.11, 95% CI: 1.13-8.60). Although not statistically
 262 significant, based on the point-estimate, ringette had a clinically relevant higher rate of suspected

263 concussion (IR=0.87 suspected concussions/100 team-minutes, 95% CI: 0.34-2.24) compared to
264 ice hockey (IR=0.19 suspected concussions/100 team-minutes, 95% CI: 0.05-0.72) (IRR=4.67,
265 95% CI: 0.92-23.61) and higher rate of non-concussion injury (IR=0.58 suspected non-
266 concussion injuries/100 team-minutes, 95% CI: 0.24-1.40) compared to ice hockey (IR=0.28
267 suspected non-concussion injuries/100 team-minutes, 95% CI: 0.10-0.80) (IRR=2.08, 95% CI:
268 0.54-8.01).

269 **DISCUSSION**

270 This was the first known study to compare PC, HC, and suspected injury and concussion IRs
271 between ringette and female ice hockey. Overall, we determined that ringette had a 19% lower
272 rate of total PCs compared to female ice hockey in varsity tournament/playoff games. Given this
273 is the first study to assess in-game PC rates in ringette and female ice hockey, it is difficult to
274 compare the findings to literature in the same populations. However, the PC IRs observed in
275 ringette (IR=310.38 contacts/100 team-minutes, 95% CI: 285.40-337.54) and female ice hockey
276 (IR=382.48 contacts/100 team-minutes, 95% CI: 356.80-410.00) were comparable to that
277 previously observed in elite U15 male youth ice hockey in 2020-21 where body checking was
278 permitted (IR= 367.85 contacts/100 team-minutes 95% CI: 340.83-397.01).²⁰ The high PC IRs
279 observed provides further support for future examination of injury in ringette and female ice
280 hockey.

281

282 We demonstrated that ringette had almost a 2-fold higher rate of body checking PCs (level 4-5
283 trunk intensities) compared to female ice hockey. The explanation for the paucity of literature in
284 ringette and female ice hockey is often attributed to policy prohibiting body checking and
285 assuming that this minimizes injury risk. Despite this prohibition, our results show that PCs

286 (including body checking PCs) are still common in these sports and likely contributes to
287 increased injury risk. This finding is consistent with Keays et al. (2014) who reported that 33.7%
288 of ringette-related injuries reported to emergency departments resulted from intentional contact
289 with another player. Similarly, in female ice hockey, Decloe et al. (2012) reported that body
290 checking was responsible for 20.7% of all female ice hockey injuries consistent across all age
291 groups (ages 9-17).

292

293 Ringette was found to have a 68% higher rate of total HCs compared to female ice hockey. The
294 HC₁ and HC₂ rates observed in ringette are higher than previously reported in male U15 ice
295 hockey.²¹ Given these alarmingly high HC rates, our findings further support the need for
296 additional research in this population to target the prevention of HCs in ringette and female ice
297 hockey.

298

299 Regarding the intentionality of the contacts, ringette observed deliberate contacts 97% of the
300 time and female ice hockey 95% of the time. This aligns with the literature that suggests many
301 contacts in ringette and male ice hockey are deliberate in nature.^{4,21} Given that many contacts are
302 deliberate, this finding suggests that perhaps prevention strategies targeting better enforcement of
303 rules are necessary in both ringette and female ice hockey.

304

305 Finally, we determined that ringette had a 3-fold higher rate of suspected injury compared to
306 female ice hockey. While not statistically significant but clinically relevant, ringette was also
307 found to have higher rates of suspected concussion and non-concussion injury. These results are
308 consistent with the literature that report a high rate of injury and concussion in youth ringette

309 compared to other female team sports.^{4,6} It may be postulated that the higher suspected injury
310 rate observed in ringette is the result of the higher rates of body checking behaviours (PC level 4-
311 5 intensities) that were observed. Research has shown that body checking is associated with
312 higher rates of injury and concussion.^{22,23} Despite policies prohibiting body checking and head
313 contacts in ringette and female ice hockey, our results show that these behaviours are still
314 prevalent, with only a small proportion of them being penalized. The high incidence of suspected
315 concussion and non-concussion injuries further supports the need for additional injury
316 epidemiology research and tailored prevention strategies in these populations.

317 **LIMITATIONS**

318 As with any video-analysis study, this study was limited by the quality of video. Overall,
319 approximately 30% of the recorded games were excluded due to poor video quality. However, it
320 is unlikely that there were systematic differences in PCs, HCs, and suspected injuries between
321 the videos that were included compared with those that were excluded. Due to the nature of the
322 pre-recorded videos, differences in video quality may have arisen. However, this limitation may
323 have resulted in an underestimation of low intensity trunk impacts and other contacts, but high
324 intensity PCs were evident and likely unaffected by video quality. Further, it is likely that PCs
325 and HCs were underestimated in both sports due to contacts occurring outside the frame of the
326 camera. PCs and HCs would also be underestimated as each contact is described from the
327 perspective of the player receiving the contact, so no information about the player giving the
328 contact is recorded. However, this would likely not be systematically different between the two
329 sports. Another limitation is the difference in exposure time between sports due to differences in
330 game length (ringette games=40 minutes, female ice hockey games=60 minutes). However,
331 differences in game length were addressed in the analysis by calculating rates accounting for

332 playing exposure minutes. Lastly, the concussion criteria for video analysis used was designed
333 for professional sports where they have multiple different angles and high-quality cameras. For
334 this study, only one camera angle was used posing some challenges to the identification of
335 suspected concussions using the same criteria. Additionally, some of the 17 video signs of
336 concussion used (e.g., dazed) may be more difficult to assess in players wearing an ice hockey or
337 ringette face mask. Further, the video analysis was anonymous and not linked to any injury
338 surveillance. Future directions may consider video analysis including validation of suspected
339 injuries and penalties using injury surveillance and game records.

340 **CONCLUSION**

341 In this study we demonstrated that ringette had a 19% lower rate of total PCs compared to female
342 ice hockey, however, ringette had a higher rate of HCs (total HC, HC₁, and HC₂) and a three-fold
343 higher rate of suspected injury compared to ice hockey. Despite rules disallowing body checking
344 and HC₁s, the incidence of body checking and HC₁ rates were high and are rarely penalized in
345 both sports. These findings can be used to better understand injury mechanisms in female
346 ringette and ice hockey and to help inform future injury and concussion prevention strategies
347 targeting high intensity PCs and HCs.

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