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Lifetime prevalence of concussion among Canadian ice hockey players aged 10 to 25 years old, 2014 to 2017

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Background: *The primary objective of this study was to identify the self-reported lifetime prevalence of diagnosed concussions among Canadian ice hockey players aged 10 to 25 years old.*

Method: *Medical records were identified for n=5223 athletes whom completed comprehensive baseline assessments with a Canada-wide network of private concussion management clinics. Variables extracted included: sex, age, diagnosed history of and number of prior concussions, diagnosed health condition(s), and Post-Concussion Symptom Scale scores.*

Results: *Approximately 22% of all athletes, 21.7% of females and 21.8% of males reported that they had sustained at least one diagnosed concussion. Age was significantly associated with history of concussion as was having an additional health condition. Sex was not significantly associated with a history of concussion.*

Conclusion: *Lifetime history of concussion prevalence*

Contexte : *L'objectif principal de cette étude était de déterminer la prévalence autodéclarée au cours de la vie des commotions cérébrales diagnostiquées chez les joueurs canadiens de hockey sur glace âgés de 10 à 25 ans.*

Méthode : *Des dossiers médicaux ont été identifiés pour 5223 athlètes qui ont effectué des évaluations de base complètes avec un réseau pancanadien de cliniques privées de gestion des commotions cérébrales. Les variables extraites comprenaient : le sexe, l'âge, les antécédents diagnostiqués et le nombre de commotions cérébrales antérieures, le ou les problèmes de santé diagnostiqués et les scores de l'échelle des symptômes après la commotion cérébrale.*

Résultats : *Environ 22 % de tous les athlètes, 21,7 % des femmes et 21,8 % des hommes ont déclaré avoir reçu au moins un diagnostic de commotion cérébrale. L'âge était associé de façon significative aux antécédents de commotion cérébrale tout comme le fait d'avoir un autre problème de santé. Le sexe n'était pas associé de façon significative à des antécédents de commotion cérébrale.*

Conclusion : *Les estimations de la prévalence des*

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estimates aligned closely with estimates previously published. Future investigations should seek to establish the prevalence of concussions that occur during ice hockey games and practices alone.

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KEY WORDS: concussion history, ice hockey, prevalence, youth, young adult

antécédents de commotion cérébrale au cours de la vie concordent étroitement avec les estimations publiées antérieurement. Les enquêtes futures devraient chercher à établir la prévalence des commotions cérébrales qui surviennent uniquement pendant les parties et les pratiques de hockey sur glace.

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MOTS CLÉS : antécédents de commotion cérébrale, hockey sur glace, prévalence, jeunes, jeunes adultes.

Introduction

Over the last 10 to 15 years, annual incidence rates of sport-related concussion (SRC) among youth athletes has increased dramatically. A recent article published by Zemek *et al*. indicated that the number of concussions treated in emergency departments and physician offices across the province of Ontario demonstrated a 5.5-fold increase (per 100 000 children) from 2003 to 2013.[1] Zemek attributed this steep increase to improvements in stakeholder concussion education and awareness, improved diagnostics, and stricter return to play medical clearance requirements. However, generating annual incidence and prevalence estimates of concussion based on emergency department visits may provide a gross underestimate of the actual number of concussions, as many athletes do not present to a hospital for diagnosis or follow-up treatment.[2] To that extent, a large body of evidence suggests that head injuries often go unrecognized and underreported by adolescent aged athletes.[3-7] Estimates suggest that approximately half of all suspected injuries go unreported in this population.[8] Further investigation is required to provide more accurate estimates of lifetime prevalence of concussion among young athletes.

Incidence of SRC by sport is well documented among youth athlete populations.[9] Findings indicated that athletes in certain sports face a greater risk for SRC than others, especially those athletes involved in high speed contact sports such as rugby, ice hockey, football and lacrosse.[9, 10] Ice hockey is not only Canada's national winter sport, but also one of our most popular recreational activities for children and youth behind that of soccer and swimming.[11] In the 2017-18 Annual Report released by Hockey Canada, over 340 000 individuals between the ages of 10 and 25 were enrolled in a hockey program at any given level.[12] As such, the popularity of ice hockey in Canada places a large number of athletes at risk for SRC. Examining athlete-reported histories of diagnosed concussions at the time of preseason baseline assessment may be useful in gauging cumulative injury prevalence. Despite being retrospective in nature, asking an athlete to recall their concussion history at a time when their current playing status is not at stake (i.e., when the athlete is not at risk to be removed from play due to a suspected SRC), may provide a more accurate assessment of concussion prevalence in this population.

Examining factors related to concussion history, such as age, sex and health history, may provide an indication as to those athletes at greater risk for an additional concussion. At present, younger age has yet to be clearly established as a risk factor for concussion.[13] With respect to recovery however, evidence suggests that younger athletes take longer to recover following concussion compared to older athletes.[14-16] With respect to sex, evidence suggests that the events surrounding concussion (i.e., incidence or risk for concussion by sport, initial symptom severity, time until functional recovery, etc.) diverge between males and females.[17-19] Following concussion, females typically take longer to achieve functional recovery than do males and are also more likely to experience persisting symptoms.[20-23.] A pre-morbid history of learning disability, psychiatric illness (i.e., depression and/or anxiety), sleep disorder, and history of headache/migraine is also thought to increase an athlete's risk for persisting post-concussion symptoms.[24]

The primary objective of this study was to identify the lifetime prevalence of self-reported concussion diagnoses among Canadian ice hockey players aged 10 to 25 years old, whom presented to Complete Concussion Management Inc. (CCMI) clinics between 2014 and 2017, by age and sex. The secondary objective(s) were to: i) examine the relationship between history of concussions (including number of concussions), and an additional diagnosed health condition (i.e., learning exceptionality, history of psychiatric illness, sleep disorder, and history of headache) by age and sex, and ii) examine the relationship between history of concussion and Post-Concussion Symptom Scale (PCSS) severity score at baseline (i.e., in the absence of injury), by sex.

Methods

Study design, participants and data extraction

This was a cross-sectional study that utilized a convenience sample of youth and young adult ice hockey players aged 10 to 25 years old, involved in various levels of hockey (i.e., house league, rep, provincial, etc.). A retrospective review of electronic medical records were identified and extracted from athletes whom had participated in comprehensive preseason concussion baseline testing at any one of 107 CCMI clinics across Canada between October 2014 and October 2017. The CCMI comprehensive pre-season testing protocol consisted of a clinical interview regarding medical and concussion histories as well as the PCSS, Sport Concussion Assessment Tool 3 (SCAT3), oculomotor function testing, postural sway measuring centre of pressure area (COP), clinical reaction time, grip strength, and computerized neurocognitive testing (for athletes 13 or older). Each province had at least one clinic and clinic locations varied from urban to rural settings. Most clinics offered a myriad of clinical services beyond that of concussion management and comprehensive baseline assessments (i.e., sport medicine [MD], physiotherapy [PT], chiropractic [DC], etc.). All clinicians were licenced health care professionals (i.e., MD, PT, DC), and were trained by CCMI via the completion of a 36-hour continuing education training course for evidence-based concussion care. CCMI partnered clinics are also required to undergo a 15-hour recertification course every 24-months to retain certification. Any individual in need of assessment following a suspected concussion, or whom was interested in obtaining a comprehensive baseline assessment, is eligible to visit a CCMI clinic. CCMI network clinics do not exclusively treat athletes.

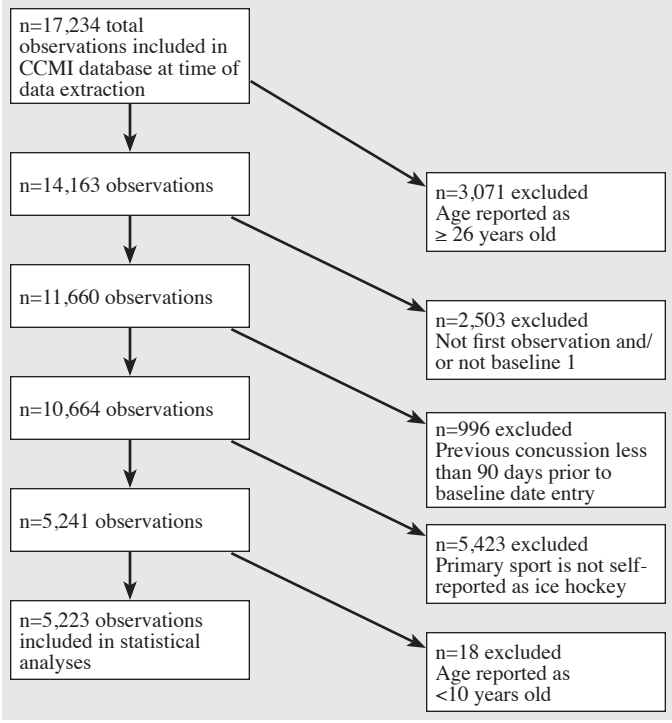

Figure 1.
CCMI database medical record exclusion flowchart.

At time of data extraction (October 2017), the CCMI database contained n=17 234 observations. First, an age filter was applied to include records from individuals aged ≤ 25.9 years old at time of record entry (n=3071 excluded; age reported as ≥ 26 years old). Duplicate records for an athlete were removed (n=2503 excluded); baseline assessments are conducted on an annual basis, and concussion assessments on an as needed basis. Only the first entry within an athlete's medical record was included in analysis. Athletes who had sustained a concussion and then participated in a concussion baseline assessment < 90 days from day of injury were also removed (n=996 excluded). This criterion was applied to ensure that PCSS severity scores had returned to baseline (i.e., pre-injury levels) following a diagnosed concussion. Athletes who did not identify ice hockey as their primary sport were also removed (n=5423 excluded). Finally, athletes < 10 years old were removed (n=18 excluded). Refer to Figure 1 for med-

ical record exclusions. All medical records identified for inclusion in this study were screened by a biostatistician (SHJ) with whom the authors consulted.

Medical records were generated and saved within the CCMI database for each athlete who participated in a baseline assessment or concussion assessment at the time of their appointment. Although clinicians collected health histories (i.e., presence of a diagnosed psychiatric illness or learning exceptionality, etc.) and concussion injury data across several domains (i.e., cognitive and oculomotor functioning, reaction time, postural sway, handgrip strength, etc.), only data pertaining to athlete age, sex, health and concussion history, and PCSS severity scores were extracted from medical records.

Health and concussion histories were self-reported by athletes during an in-person interview with a CCMI certified clinician. Each athlete was asked to respond to the following questions: i) "have you ever been *diagnosed* with a concussion?" ii) "if yes, how many?", iii) "when was the most recent?", iv) "how long did it take you to recover from the most recent concussion?", and v) "do you still experience symptoms from your most recent concussion?". Only responses pertaining to questions i) and ii) were used within analyses. Data pertaining to the following health history variables were also extracted: *diagnosed* learning exceptionality, ADD/ADHD, depression, anxiety, sleep disorder, and history of headache. Concussion-like symptom severity scores (as reported on the PCSS, a 22-item measure with a total possible score of 132) were extracted and stratified by number of concussions for comparison between sex groups. The PCSS has been found to have a high internal consistency in both healthy (Cronbach's α = 0.89-0.94) and concussed samples (α = 0.92-0.93)[25], and consists of a four factor structure: somatic, cognitive, emotional and sleep-related symptoms[26]. For the purposes of age comparison, athletes aged 10 to 12 years old were defined as "youth", 13 to 18 years old as "adolescent" and 19 to 25 as "young adult".

Pre-participation consent was provided by athletes and/or their guardians for the collection and use of de-identified data for research purposes. This investigation was approved by the Research Ethics Board at the Canadian Memorial Chiropractic College, Toronto, Ontario (protocol #162009).

Data analysis

De-identified athlete medical records were extracted from the CCMI database and exported into an encrypted excel spreadsheet. The spreadsheet was then moved into Statistical Package for the Social Sciences software (SPSS) in January 2018. Mean age (SD) was calculated for the total sample and each sex group. Chi square statistics were calculated for the lifetime prevalence of concussion among sex and age groups (see Table 1). To allow for comparison of the effect size, odds ratios were calculated for a history of concussion for both sex and age groups (see Table 2; note that history of concussion was dichotomized as "yes" or "no"). Chi square statistics were also calculated

Table 1.

Lifetime prevalence of self-reported diagnosed concussions among Canadian ice hockey players aged 10 to 25 years old presenting to CCMI clinics between 2014 and 2017, by sex and age. Note: percentages reflect the proportion of the row total.

	Number of Prior Concussions								χ^2	P-Value
	0		1		2		3+			
	N	%	N	%	N	%	N	%		
Total Sample	4085	78.2	743	14.2	269	5.2	126	2.4	—	—
Sex	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**		
Male	3265	78.2	602	14.4	212	5.1	97	2.3	1.44	0.70
Female	820	78.3	141	13.5	57	5.4	29	2.8		
Age Category	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**		
Youth (10 to 12 yrs.)	1602	83.4	238	12.4	67	3.5	13	0.7	206.8	<0.001
Adolescent (13 to 18 yrs.)	2352	76.5	466	15.2	173	5.6	82	2.7		
Young Adult (19 to 25 yrs.)	131	57.0	39	17.0	29	12.6	31	13.5		

Table 2.

Association between history of self-reported diagnosed concussion (vs. none) by age, sex and select medical histories among Canadian ice hockey players aged 10 to 25 years old presenting to CCMI clinics between 2014 and 2017. Legend: N= no, Y= yes, OR = odds ratio

		No History Concussion	History of Concussion	OR	95% CI	P-Value
Age Category						
Younger (10 to 18 yrs.)		3954	1039	—	—	—
Older (19 to 25 yrs.)		131	99	2.88	2.20-3.77	<0.001
Sex						
Male		3265	911	—	—	—
Female		820	227	0.99	0.84-1.17	0.93
Medical History						
Learning Exceptionality	N	3882	1047	—	—	—
	Y	203	91	1.66	1.29-2.15	<0.001
Prior Psychiatric Diagnosis	N	4003	1068	—	—	—
	Y	82	70	3.20	2.31-4.43	<0.001
Sleep Disorder	N	4066	1128	—	—	—
	Y	19	10	1.88	0.88-4.09	0.12
History of Headache	N	3406	873	—	—	—
	Y	679	265	1.52	1.30-1.79	<0.001

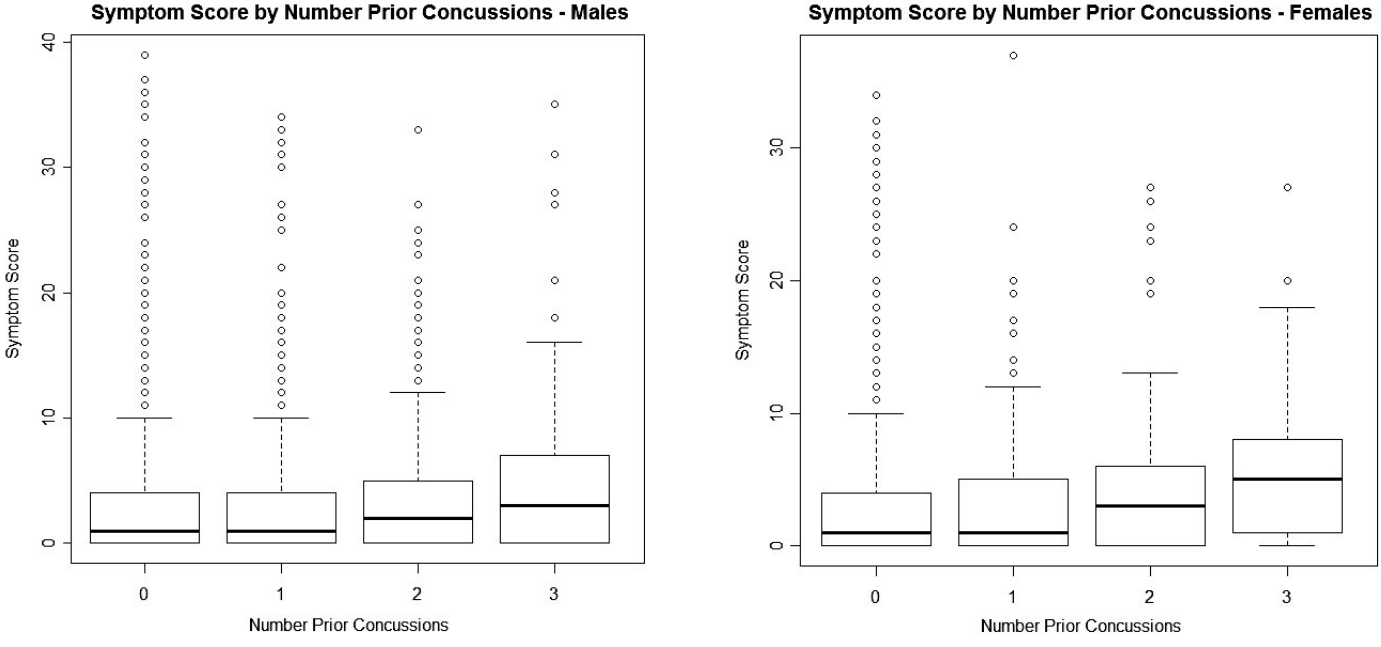

Figure 2.

Median PCSS score by prior number of concussions and sex.

within each sex group for prevalence of concussion(s) by age and health history (see Tables 3 and 4). Lastly, box and whisker plots were used to compare PCSS severity scores for males and females by number of previous concussions (see Figure 2). Statistical significance was set at p=0.05 for all tests.

Results

A total of n=5223 medical records from ice hockey players between the ages of 10 and 25 years old were included in this study. This sample represented approximately 1.5% of the entire youth, adolescent and young adult population enrolled in Hockey Canada programs in the 2017-2018 season (approx. n= 345 000).[12] Males (n=4176) comprised 79.9% of the entire sample. The mean age was 13.6 years old (SD 2.67) for the entire sample, 13.4 years old (SD 2.25) for males, and 14.3 years old (SD 3.81) for females. Approximately 22% of all athletes had indicated they had been diagnosed with at least one prior concussion. The number of males and females whom reported a history of

Table 3.

Cross tabulation of number of concussions by age and select medical diagnoses among male Canadian ice hockey players aged 10 to 25 years old presenting to CCMI clinics between 2014 and 2017.
*Legend: learning exceptionality = aggregate variable containing athletes who self-reported a learning disability, ADD or ADHD diagnosis; prior psychiatric diagnosis = aggregate variable containing athletes self-reporting a diagnosis of depression or anxiety; * cells had lower than expected counts – interpret p-value with caution.*
Note: percentages reflect the proportion of the row total.

	Number of Prior Concussions									
Age Category	**0**		**1**		**2**		**3+**		χ^2	**P-Value**
Youth (10 to 12 yrs.)	1264	82.4	202	13.2	57	3.7	11	0.7	106.7	<0.001
Adolescent (13 to 18 yrs.)	1935	76.3	385	15.2	144	5.7	71	2.8		
Young Adult (19 to 25 yrs.)	66	61.7	15	14.0	11	10.3	15	14.0		
Medical History										
Learning Exceptionality	180	69.0	38	14.5	21	8.1	22	8.4	52.6	<0.001
Prior Psychiatric Diagnosis*	56	58.3	13	13.6	14	14.6	13	13.5	75.7	<0.001
Sleep Disorder *	16	69.6	3	13.0	1	4.4	3	13.0	11.7	0.008
History of Headache	528	73.1	118	16.3	50	6.9	27	3.7	18.5	<0.001

Table 4.

Cross tabulation of number of concussions by age and select medical diagnoses among female Canadian ice hockey players aged 10 to 25 years old presenting to CCMI clinics between 2014 and 2017.
*Legend: * cells had lower than expected counts – interpret p-value with caution.*
Note: percentages reflect the proportion of the row total.

	Number of Prior Concussions									
Age Category	**0**		**1**		**2**		**3+**		χ^2	**P-Value**
Youth (10 to 12 yrs.)	338	87.6	36	9.3	10	2.6	2	0.5	103.2	<0.001
Adolescent (13 to 18 yrs.)	417	77.5	81	15.1	29	5.4	11	2.0		
Young Adult (19 to 25 yrs.)	65	52.9	24	19.5	18	14.6	16	13.0		
Medical History										
Learning Exceptionality*	23	69.7	2	6.0	6	18.2	2	6.1	13.2	0.004
Prior Psychiatric Diagnosis*	26	46.4	13	23.2	9	16.1	8	14.3	52.5	<0.001
Sleep Disorder*	3	50.0	0	0	2	33.3	1	16.7	14.3	0.003
History of Headache	151	68.4	42	19.0	16	7.2	12	5.4	18.8	<0.001

concussion declined as the number of prior concussions increased (i.e., fewer individuals reported multiple concussions compared to a single concussion). Sex and number of prior concussions were not significantly associated with one another ($\chi^2(3) = 1.44$, p=0.70). Stratified by age, a similar trend was identified; within each age group, fewer athletes reported multiple prior concussions compared to zero or one prior concussion. The association identified between age and number of prior concussions was significant ($\chi^2(6) = 206.8$, p=<0.001).

Calculated odds ratios provided an indication as to the effect size between age, sex, health history and history of concussion. Like above, athletes in the older age group were 2.88 times more likely (CI 95%, 2.20 to 3.77) to have had a history of concussion compared to younger athletes. The odds of having a history of concussion was not significantly associated with an athlete's sex. Having had at least one prior concussion was significantly associated with a history of learning disorder (OR=1.66, p<0.001), a previously diagnosed psychiatric illness (OR=3.20, p<0.001) and a history of headache (OR=1.52, p<0.001). History of sleep disorder was the only health condition not found to increase an athlete's odds of having a history of concussion (p=0.12).

Tables 3 (males only) and 4 (females only) stratify number of prior concussions by age and medical history. Among male athletes, number of prior concussions was significantly associated with an increase in age ($\chi^2(6) = 106.7$, p <0.001). Irrespective of age, fewer males reported a history of multiple concussions (i.e., two and three or more) compared to males who reported zero or one. One exception was noted among young adult males; a greater proportion of males reported three or more prior concussions (14.0%) as compared to two (10.3%). Significant associations between number of prior concussions and each health condition were also identified. Note the low cell counts for prior psychiatric diagnosis and sleep disorder categories.

Similar to findings among males, data from female athletes indicated there was a significant association between number of prior concussions and age ($\chi^2(6) = 103.2$, p <0.001). Again, fewer females reported multiple concussions compared to zero or one. Significant associations between each health condition and number of concussions was identified, but due to low cell counts (except for a history of headache) findings should be interpreted with caution. When comparing concussion histories across sex groups, a greater proportion of males reported a history of concussion (of any number) within each of the age categories. Two exceptions were noted; a greater percentage of females in the young adult age category reported one (19.5% vs. 14%) and two prior concussions (14.6% vs. 10.3%) compared to males in the same age category.

A positive association was identified between PCSS severity score and prior number of concussions as seen in Figure 2; symptom severities increased with each additional concussion that was reported. Symptom severity score appeared to be similar among the sexes for zero and one prior concussion. However, male and female symptom severities diverged in the two and three or more concussion categories, with females having higher symptom severity scores than their male counterparts. Pairwise comparisons and tests of significance were not calculated.

Discussion

With respect to the entire sample, 21.8% of athletes reported that they had been diagnosed with a least one prior concussion. Estimates were comparable within each sex group (21.8% and 21.3% for males and females, respectively). Prevalence declined as number of concussions increased (i.e., fewer athletes reported two or three or more concussions as compared to one or none). A similar trend was identified within each sex group, with the exception of males in the young adult category where more athletes reported three or more concussions (14%) than two (10.3%). Sex was not significantly associated with number of prior concussions, but age was. Categorized as a young adult and having an additional health condition was associated with an increase in the odds of having a history of concussion. Similar trends of association were noted within each sex group. With respect to baseline PCSS severity scores, females with a history of two and three or more concussions reported greater symptom severities at baseline than did males with the same concussion histories.

Four previously published investigations (three pertaining to high school aged athletes and one to college aged athletes) on the prevalence of concussion in ice hockey were identified and compared with our findings. Similar to our investigation, Brooks *et al*. also examined concussion prevalence among Canadian youth ice hock-

ey players aged 13 to 17.9 years old (n=615).[27] Among their total sample, 62.1% of athletes reported no history of concussion, 30.1% reported one (males = 32.9%; females = 20.4%), 5.9% reported two (males = 6.2%; females = 4.1%), and 1.1% reported three prior concussions (males = 1.2%; females = 1.0%). Notably, the proportion of athletes within Brooks' sample whom reported a history of at least one prior concussion was more than double that of our athletes in the same age group (i.e., 13 to 18 years old; 30.1% vs. 14.2%). Larger discrepancies in prevalence were also noted among Brooks' athletes than ours when comparing number of previous concussions by sex. Kontos *et al*. also calculated prevalence of concussion among ice hockey players aged 12 to 18 years old (n=397), but included only American athletes.[28] Findings indicated that 73.5% of their athletes had no history of concussion, 18.6% reported one, 6.3% reported two and 0.8% reported three prior concussions; prevalence estimates for zero and one prior concussion were much closer to ours than Brooks' were. In a 2018 multi-sport study conducted by Veliz *et al*. on American 8th, 10th and 12th grade students (n=25 048), 81.6% of students reported no prior concussion and 18.4% reported at least one.[29] Again, this was similar to the prevalence for the same concussion categories within our investigation (15.2%). Looking exclusively at the students whom were ice hockey players (n=391), 23.0% reported one and 15.9% reported a history of multiple concussions, both of which were much greater than the estimates generated from our sample of the same age. Overall, prevalence estimates generated from our investigation for the adolescent age group alone (i.e., 13 to 18 years old) were similar but slightly more conservative than those referenced above. For example, 15.2% athletes in our adolescent age group (i.e., 13 to 18 years old) reported one prior concussion as compared to 30.1%[27], 18.6%[28], and 23.0%[29]. When considering all athletes included in our sample (regardless of age) who reported a least one prior concussion, our prevalence estimates (~22%) come much closer to that of the estimates referenced above. One important consideration for readers to note here is that athletes with a history of concussion face an increased risk for subsequent concussion.[30,31] In other words, once an athlete has sustained one concussion, they are more likely to sustain another.

The final study for comparison included college aged athletes. Katz *et al*. captured n= 15 681 National Collegiate Athletic Association (NCAA) athletes, of which n=221 were ice hockey players.[32] They found that 58% of all players, 57% of males and 64% of females reported no prior concussion. Prevalence estimates declined with each additional concussion (i.e., one prior concussion; total sample: 28%, females: 25%, males: 29% vs. two prior concussions; total sample: 9%, females: 8%, males: 10% vs. three or more prior concussions; total sample: 5%, females: 4%, males: 5%), which was the same trend identified within our investigation and both Brooks' and Kontos'. Prevalence estimates from our investigation were more conservative for athletes within the same age range (i.e., young adult; 19 to 25 years old) whom had zero (57.0%) or one prior concussion (17.0%), but inflated for athletes with two (12.6%) or three or more concussions (13.5%). Similar to our findings, Katz' prevalence estimates declined as the number of prior concussions increased. In general, prevalence of concussion (of any number) was greater among Katz' collegiate aged athletes than our high-school aged athletes and those in the studies described above. This trend is likely explained by greater cumulative athletic exposure hours that accompany older age (i.e., a 21-year-old will have participated in and accumulated a greater number of hours playing in ice hockey games and practices than a 15-year-old who started playing hockey at the same age).

Readers may wish to note that any discrepancies identified with respect to lifetime concussion prevalence estimates between the referenced studies may be explained by methodological differences in how history of concussion was assessed and reported (i.e., diagnosed concussions as reported in a medical record vs. self-reported diagnosed concussions only vs. self-reported diagnosed and undiagnosed concussions vs. parent and/or athlete self-reports); each of the above referenced studies, including our own, assessed athlete concussion histories in a slightly different manner. In the case that concussion histories were generated based on athlete self-report, poor memory recall and limited knowledge of concussion and the associated symptoms may also explain variability in prevalence estimates. Although each of the above studies included ice hockey players, concussions reported by athletes did not appear to be limited to only those that occurred whilst playing ice hockey.

Within our investigation, athletes who reported an additional health condition (other than a sleep disorder)

were significantly more likely to have had a history of concussion than athletes who did not. However, timing of diagnosis in relation to the occurrence of concussion was not acquired from athletes. As such, definitive statements pertaining to if these conditions increased the athlete's risk for concussion cannot be made. Health conditions, like those assessed within our investigation, may have important implications on recovery outcomes following a SRC. One systematic review summarizing predictors of clinical recovery following a SRC in athletes found several pre-injury health conditions (including but not limited to ADHD, a history of headache, familial and personal psychiatric history, as well as previous concussion) were associated with poor post-concussion outcomes (i.e., persisting post-concussive symptoms) [24]. Refuting evidence was also cited.

At time of baseline assessment, our athletes were also asked to report on the presence and severity of concussion-like symptoms via the PCSS. Both males and females reported similar symptom severities when stratified by prior number of concussions (see Figure 2). This trend is both supported[33, 34] and refuted[35-37] by the existing literature. Findings from one large scale meta-analysis (n=42 493) on high school and college aged athletes (inclusive of ages 12 to 26 years old) indicated that females were 43% more likely to report at least one concussion-like symptom at baseline compared to males. Specifically, females had significantly higher odds of reporting: vision/ hearing problems, headache/migraine, difficulties concentrating, energy/sleep and emotional disturbances.[38] Irrespective of sex, a history of concussion has been associated with greater concussion-like symptom reports in the absence of injury (i.e., at baseline).[27, 39] The take home message here being that clinicians must consider the impact that single and multiple prior concussions have on the short and long-term health of young athletes.[31]

Examining injury reporting behaviours specific to young athletes is critical to interpreting prevalence trends. This is especially important given the lack of an objective test for diagnosing a concussion. Unless observed by a parent/coach/trainer/game official, athletes must come forward to seek medical attention if they suspect a concussion has occurred. As noted above, approximately half of all suspected concussions go unreported by youth athletes.[8] Sex has also been shown to impact reporting behaviours; in one study, male high school aged athletes were 4 to 11 times more likely than females to not report a suspected concussion to their coach or parent.[40] Despite sex differences, athletes cited the following reasons for not reporting a SRC: 1) "I thought my coach would get mad", 2) "I thought my teammates would think I'm weak", 3) "I didn't want to let my team mates down", 4) "I thought my coach would think I'm weak", and 5) "I thought my parents would get upset".[40] In a separate study, being female was associated with an increase in SRC knowledge and improved concussion reporting behaviours as compared to males.[41] With respect to age, younger athletes may not be as familiar with concussion symptoms or the negative consequences associated with non-reporting behaviours, thus resulting in fewer injury reports. Clinicians should note that athletes who fail to report a SRC may face an increased risk for a subsequent concussion and poor long-term health outcomes.[42]

Strengths and limitations

To our knowledge, this study offers the largest sample of ice hockey players compared to the other prevalence studies referenced. However, athlete records included in our study represent a very small proportion (~1.5%) of all Hockey Canada registrants. As such, the sample captured and prevalence estimates generated may not be representative of the population as a whole. Our study also offers comparison of concussion prevalence rates across a wide age range (i.e., middle school to collegiate aged athletes). Noting however that college aged athletes were largely underrepresented within our sample (4.4%). Caution should be used if generalizing study findings to a young adult age group. One unique aspect of our study was that we examined the association and calculated odds ratios between several health conditions and history of concussion. Due to the limited health history information that was collected from athletes, the identified relationships lack temporality; we do not know if a reported health condition occurred before or after a concussion occurred (if any). Furthermore, athletes were only asked to report *diagnosed* health conditions. We did not cross reference athlete self-reports with official medical records. Finally, diagnosed concussions reported by the athletes were not limited to those that occurred whilst playing hockey. As such, we cannot make any conclusions regarding prevalence of concussion within the sport of ice hockey exclusively. Athletes also provided retrospective injury self-re-

ports which can be problematic and subject to poor memory recall. Athletes may have inflated or underreported their history of concussion due to any number of reasons, some of which are discussed above. Reported diagnosed concussions were not cross-referenced with official medical records.

Conclusions

Approximately 22% of ice hockey players presenting to CCMI clinics reported at least one prior concussion, which was similar to previously published prevalence estimates. A smaller proportion of athletes (~7.6%) reported a history of two or more prior concussions.

Sex was not found to be significantly associated with an increase in the odds of having a history of concussion. Although young adults made up a very small percentage of the total sample, a greater proportion of these athletes reported a history of concussion (of any number) compared to younger age groups. Older age was significantly associated with having a history of concussion. This was attributed to a greater overall athletic exposure (i.e., greater cumulative number of hours spent in games, practices and training) to injury. Athletes whom reported an additional health condition (other than a sleep disorder) were significantly more likely to have a history of concussion compared to those athletes without an additional diagnosis. Lastly, number of prior concussions appears to be positively associated with concussion-like symptoms reported via the PCSS in the absence of injury.

Although risk for SRC cannot be removed entirely from the sport of ice hockey, revision of player-to-player contact policies in youth hockey (such as barring body checking under the age of 13) has consistently demonstrated a protective effect in reducing athlete risk for SRC.[31] Given the proportion of ice hockey players whom reported a previous concussion, stakeholders are encouraged to consider the availability of educational, injury management and injury prevention strategies that are in place and accessible at the athlete level. Moving forward, subsequent investigations should seek to establish prevalence estimates of SRC that occur *while playing* ice hockey. Acquiring information from athletes with respect to timing of an additional health condition (i.e., present pre- or post-concussion) would help to better define any risk and recovery implications that may exist. In turn, clinicians can offer a more informed approach to managing and protecting athletes at risk for prolonged recovery and subsequent SRCs.

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