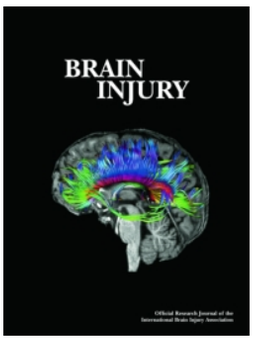

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ORIGINAL ARTICLE

# Depression in youth recovering from concussion: Correlates and predictors

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**ABSTRACT**

*Objectives*: Although depression can be a serious consequence of concussion, little is known about the factors that predict depression and concussion recovery outcomes in children. The purpose of this study was to explore the risk and possible predictors of developing significant depressive symptoms in children recovering from concussion. *Methods*: A prospective cohort study was conducted in a paediatric tertiary care clinic. Depression data were collected from 92 children using the Children's Depression Inventory-2 (CDI-2) screening tool. Correlations, *t*-tests and logistic regression were used to examine the associations between depression scores and demographic as well as injury-related factors. *Results*: Depressive symptoms were found in 22% of the children (T score on CDI-2 >65). Children with evidence of depressive symptomatology had significantly higher mean post-concussive symptom inventory (PCSI) scores in recovery ($p = 0.004$) than children who were not depressed. Variables of i) Sex; ii) hospital admission; iii) number of head injuries; iv) post-concussion symptom score and v) experience of prolonged symptoms were predictive of clinically significant CDI T scores, explaining 36% of the variation in the binary logistic model. *Conclusion*: Depression is commonly reported in this subset of children. High post-concussive symptom scores and hospital admission were strong predictors of depression. Screening for depression should be standard practice in concussion management in children and youth.

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Child; concussion; mild traumatic brain injury; post-concussion syndrome; depression and anxiety; children's depression inventory-2

In the USA, the incidence of concussion is reported to be between 1.7 and 3.8 million individuals per year; more than half of them are children [1]. Recent figures from sports injuries alone show that the prevalence of concussions doubled in the 8–19-year-old age group from 1997 to 2007 [2] due in most part to increased community awareness and subsequent policy changes and new guidelines [3,4]. Children are a vulnerable group because of their developing brains and susceptibility to prolonged recoveries compared to the adult population [5,6,7]. Children also have the potential for many injuries over their lifespan especially given that concussion is a predictor of future concussions [8,9].

Concussion as defined by the World Health Organization (WHO) results from a blow or force to the head and consists of one or more of the following criteria: loss of consciousness for less than 30 minutes, confusion or disorientation, post-traumatic amnesia of less than 24 hours and/or transient neurological symptoms [10]. There remains a considerable lack of agreement in the diagnosis or label of concussion[i], mild traumatic brain injury (mTBI) or mild closed head injury particularly in children [11,12]. Currently, in clinical practice, there is variation in injuries even when a diagnostic label is given [11].

Recovery from childhood concussion has varied trajectories [13,14] and is currently described on the basis of the length of symptom presentation: under 1 month, between 1 and 3 months and over 3 months. Symptoms of concussion are categorized as somatic (e.g., headache and balance issues), emotional (e.g., irritability and anxiety), cognitive (e.g., difficulty concentrating and remembering) and sleep symptoms [15].

Childhood concussive injuries typically resolve in days or weeks, but some of these 'mild' injuries can have serious and prolonged health consequences [16,17]. When symptoms last more than 3 months, they can significantly affect the child's everyday life and may intensify emotional or depressive symptoms [18]. Children and adolescents are at higher risk for prolonged symptoms after concussion, with 11–30% of children reporting ongoing symptoms at 3 months post injury [19,20].

While there are frequent references to the risk of developing depression after concussion, there is little evidence specifically about this result in children. Psychosocial outcomes after childhood concussion are beginning to receive more attention, as depression in young people profoundly affects their participation in school, social and physical activities as well as putting youth at risk for suicidal behaviour, substance abuse and negative life trajectories [21,22]. The prevalence for major depressive disorder in the general population is reported to be 1–3% in children [23] and increasing in adolescents to a 7.5 past-year prevalence [24,25]. Girls report depression more than boys beginning at 12 years of age and increasing to a 2:1 ratio in later adolescence and adulthood [23,26]. Injury or illness increases the susceptibility to depression [27,28]. Within the first year after concussion, adults demonstrate rates of 15–18% of new onset depression [29,30].

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Recent studies investigating depression after concussion in children fall into two categories: 1) those investigating the risk of depression based on exposure to concussion and 2) those investigating depression that occurs shortly after injury, complicating the recovery from concussion. Consistent results from the former studies show an increased likelihood of becoming depressed when there is a history of concussion or traumatic brain injury (TBI) [31,32]. However, studies exploring depression that occurs during recovery from concussion are less conclusive in determining prevalence. Two prospective studies, the latter with an orthopaedic control group, found an 11% and 21.4% incidence of new onset of depression/anxiety in children within 6 months after their injury [33,34]. Both of these studies drew their samples from children who were hospitalized for mild injuries, which potentially introduces selection bias as more severe cases are hospitalized. A recent cross-sectional study of post-concussive children aged 7–17 years examined them 1–3 years post injury for depression and post-concussion symptoms [35]. Depression was found to be uncommon and was experienced by only 3% of their sample [35]. Differences in sample selection and inclusion criteria, definitions of concussion, follow-up time and additional methodological issues make it difficult to draw substantive conclusions about the incidence of depression in children recovering from concussion. More studies are needed to close the gaps in knowledge or to confirm and add to some of these preliminary conflicting findings. Investigations specifically representing children with concussion need replication. Studies also need to focus on the period of recovery from concussion and to span both childhood and adolescence if we are to fully understand the issue of depression in relation to childhood concussion.

Research studies examining the association between depression and concussion have identified factors that may predict the incidence of depression after concussion. Many non-injury-related factors are reported to be associated with the onset of depression after concussion: older child, family history of anxiety [34], lower socioeconomic status [36] and post-injury stress [33]. In addition, many injury-related factors in the adult population have been identified as risk factors for depression, including multiple brain injuries, number and severity of symptoms, mechanism of injury, hospitalization and imaging abnormalities [37–39]. To date, there have been very few studies conducted with children. One paediatric prospective cohort with orthopaedic controls demonstrated that the severity of injury and post-injury stress predicted the onset of depression [33].

Research determining both the incidence of depression and the factors that predict risk for depression after concussion is in the early stages. More work needs to be done to understand the incidence of depression in children recovering from concussion and to highlight factors that predict depression in children who are still in recovery from concussion. Determining the factors that increase the risk for depression post concussion can lead to strategies for effective prevention and early intervention.

The purpose of this study is to explore the risk of depression in a cohort of children and youth recovering from concussion, and to identify predictors of depression during the recovery period. It was hypothesized that depression would be associated with prolonged recovery from concussion. It was also hypothesized that there would be gender and age differences in depression, with higher rates among adolescent girls. Finally, it was hypothesized that injury-related factors (i.e., number of head injuries, symptom scores and hospitalization) would increase the risk of developing depression.

## Methods

A prospective cohort study was conducted with children recovering from concussion through the acquired brain injury (ABI) clinic ($n$ = 477) at a tertiary care children's hospital. This tertiary care centre, located in Southwestern Ontario, serves a region of approximately 2.3 million people. Approximately 45% of referrals to this clinic are received from the emergency department and hospital wards, and 55% are received from community physicians and outlying hospitals. This provides a mixture of children who have had both acute and complex care needs.

### *Sample*

Due to the interest in depression, a protocol of screening for depression was implemented as a pilot project in the ABI clinic from April to June 2013 with full implementation to consecutively presenting patients from August to December 2013. Thus, a prospective cohort of 92 consecutive children who were newly referred or had follow-up appointments scheduled were administered the CDI-2 [40] if they were between the ages of 8 and 18 years. Data of those who met the following inclusion criteria were included for analysis:

(1) Physician label of mTBI/concussion documented in the medical record*
(2) completion of a CDI-2 [40]
(3) completion of one or more Post-Concussion Symptom Inventory checklists [15]

*Physicians in this clinical environment used the WHO diagnostic criteria as there is no universally accepted definition of concussion.

Children who had open head injuries, injuries sustained from child abuse and those from intoxication were not included. Participants were not excluded if they required hospitalization or had intracranial lesions or skull fractures.

The Hamilton Integrated Research Ethics Board approved the prospective collection of data from the clinical ABI database. Consent was covered through this process.

### *Procedures*

Upon initial presentation to the ABI follow-up clinic, a thorough history is obtained and a review of medical records is completed by the physician. This interview of parent and child collects demographic data, history of the present injury and complaints as well as any past injuries and pre-injury data

including developmental history, school performance and past mental health issues. Subsequent follow-up visits to the clinic include a review of the medical history and a physical examination as well as follow-up interviews in regard to how the concussion symptoms are impacting their lives. School performance is closely monitored, and problems are identified through clinical interview. A decrease in academic standing is documented when those school difficulties noted post-concussive injury result in decreased academic marks by more than 10%, reduced academic workload or clinician documented symptoms of decreased concentration, difficulty coding and decoding, reading or studying.

Parents and children also each independently completed a Post-Concussion Symptom Inventory (PCSI) [15] and the CDI-2 short version (CDI-2S) [40] at the appointment. The PCSI was completed at each clinic appointment from admission to discharge, detailing symptoms experienced in the past 2 days. Data were collected prospectively, and some children who were being followed long term had up to three symptom evaluations recorded, with time three being the most current symptom score. The scores from the CDI-2S were obtained every 3 months if children were being followed long term; however, it was decided to use only those CDI-2S scores from the first administration as there were very few children (4) with more than one set of depression scores. Depression data were collected over a period of 8 months in 2013.

### Measures

The CDI-2 is both a self-report and parent-report measure of the extent and severity of depressive symptoms [40]. The screening tool (CDI-2S) consists of 12 questions and requires one of three response options: the child chooses the statement that best describes their feelings or moods in the past 2 weeks. Statements represent the range of severity of the symptom from 0 (none) to 2 (definite). Scores are totalled, and raw scores are converted to T scores. A T score of 65 (1.5 SD above the mean) is generally considered to indicate a clinically significant level of depressive symptomatology. This screening tool has a high correlation with the full-length self-rated form ($r = 0.95$, $p < 0.001$) and has been validated for use with medically ill children [41]. There are three questions dealing with depressed mood and irritability, three questions regarding physical symptoms, one about diminished pleasure, one dealing with cognitive symptoms and the rest are about feelings of low self-esteem, worthlessness and hopelessness.

The parent measure is a parallel questionnaire that includes 17 questions with scores that are grouped into emotional, functional and total score domains. Again, parents are asked to consider the child's moods and feelings in the past 2 weeks.

The Post-Concussion Symptom scale [15] is a symptom inventory derived from the original sideline assessment developed by the Pittsburgh Steelers of the National Football League [42]. This clinically driven tool has many variants and has been adopted and standardized into such tools as the Acute Concussion Evaluation [15], the Sport Concussion Assessment Tool [43] and the Immediate Post-Concussion and Cognitive Test [44], which is commonly used to make return to sport decisions. Most of the variants have a 7-point Likert scale to measure intensity of symptoms and others have a yes/no dichotomous scale [45]. It is a quick and clinically useful way of tracking symptom resolution through serial administration over days or weeks. The PCSI [15] is one of the variations and lists 22 concussion symptoms in the domains of physical, cognitive, emotional and sleep and has a yes/no dichotomous scale [45]. Both children and parents fill in this checklist independently, answering yes (1) or no (0) to whether the child has experienced each symptom in the past 3 days. The 'yes' scores are added for a total score out of 22. The scales are valid in measuring change in symptoms over time; however, psychometric evidence is stronger for adolescents than younger children [46].

Symptoms of depression and post concussive symptoms are known to overlap; however, these measures actually have only two items that are worded similarly: irritability and fatigue. Sadness and decision-making are also asked about in both measures but are worded quite differently.

### Data analysis

Our sample size of 92 is adequate to provide a valid model to estimate risk in logistic regression analyses. The value of 10 events per variable and higher is recommended by Peduzzi et al. for both proportional hazards and logistic regression analyses [47]. Below this, the statistical model may not be valid. We will have one primary outcome (depressive symptoms indicated by a T score >65 on CDI-2S) with five predictors.

For analysis, children were categorized based on the CDI T-score of ≥65 ($n = 20$) indicating depression or <65 ($n = 72$) indicating no depression. Initially, to test for group differences, chi-square and student $t$-tests were conducted on demographic variables and clinical characteristics. As this was an exploratory study, significance was two-tailed and set at $p \leq 0.05$. Much of the data of interest were not normally distributed, not uncommon in brain injury research, so a decision was made to use non-parametric statistics for correlations and regression. Correlations between depression and injury and non-injury-related variables were determined using Spearman's Rho. Logistic regression was used to model the predictor variables of interest with the primary binary outcome: a clinically significant level of depressive symptoms either present ('yes' T score ≥65; coded 1) or not present ('no' T score <65; coded 0). Predictor variables were selected based on our hypotheses, results from descriptive statistics and univariate analysis using binary logistic regression. The selected variables were subjected to linear regression analysis to test for collinearity. The data did not violate the multicollinearity assumption with variance inflation factors well below the cut-off of 10 (range from 1.29 to 2.36). A combination of forward and backward selection was used for model fitting using the most significant candidate covariates and then eliminating those with $p$ values over 0.6 [47]. All data analysis was done using IBM SPSS Statistics for Windows, Version 22.0 [48].

## Results

The study sample consisted of 92 children aged 7–18 years included 56 girls and 36 boys with a mean age of 15 years ± 2.5. Depression screens were administered a median of 3.7 months (2 weeks–35 months) after injury (see Table 1). PCSI scores were obtained a mean of 9.2 weeks for Time 1 at their initial clinic appointment, 5.6 months for Time 2 and 8.5 months for Time 3. Information on demographic and clinical characteristics by outcomes is presented in Table 2. Although 30% of the children were hospitalized, the majority for 24 hours, there were seven children who required longer admissions due to musculoskeletal, spinal and/or facial injuries (2–14 days). The study sample of 92 children differed from the larger dataset of 477 children followed in the ABI clinic in a few ways: there were more girls in our subset (64% compared with 44%); the PCSI means were higher in girls (9.91 vs. 8.26), and 70% of the 92 children had symptoms for 3 months or more compared to only 52% in the larger dataset.

### Non-injury-related factors

In comparing children classified as depressed versus non-depressed (chi-Square analysis; $\chi^2$), there were no significant differences in age ($p = 0.85$), sex ($p = 0.79$), premorbid history of learning issues ($p = 0.61$) or premorbid history of mental health issues ($p = 0.90$). Significant differences, however, were noted in decreased academic standing after concussion ($\chi^2 = 4.6$, $df = 1$, $p = 0.03$) as well as in persistence of concussion symptoms (>3 months duration) ($\chi^2 = 6.3$, $df = 1$, $p = 0.01$). Children with depression were less likely to be succeeding in school after concussion. Prior to their injury, 7.6% of children had documented learning issues, whereas, after injury, 53% reported a decrease in school performance.

Correlational analysis using Spearman's Rho for categorical variables (see Table 3) showed strong positive associations between depression scores (yes/no) and persistence of concussion symptoms (yes/no) over 3 months ($r = 0.483$, $p < 0.01$), and between depression scores and decrease in academic standing ($r = 0.431$, $p < 0.01$).

**Table I.** Time from injury to depression screen.

| Time from injury to screen (month) | Total number $N = 84$* (%) | +CDI T ≥65 $N = 19$ (%) |
|---|---|---|
| <1 | 18 (21) | 4 (21) |
| 1–3 | 20 (24) | 3 (16) |
| 4–6 | 20 (24) | 5 (26) |
| 7–12 | 7 (8) | 5 (26) |
| >12 | 19 (23) | 2 (11) |

*Hospital records incomplete with some dates of injury.
+Children's depression inventory *T* score.

### Injury-related factors

In comparing children classified as depressed versus not depressed, chi-square analysis showed no significant differences in reports of multiple head injuries ($p = 0.46$), cause of injury ($p = 0.35$), computerized tomography abnormalities ($p = 0.67$) or hospital admissions ($p = 0.67$). Significant differences were, however, found in the number of concussion symptoms as reported on the PCSI. Children with depression had higher initial clinic PCSI mean scores ($p = 0.004$) and higher PSCI scores reported on the third clinic visit ($p = 0.041$). Length of hospital stay was also found to be significantly higher in children who were subsequently classified as depressed (T score > 65 on the CDI-2-S) ($p = 0.003$).

Correlational analysis showed significant positive associations between depression scores and the number of

**Table II.** Characteristics of sample by CDI-2 scores.

| | CDI ≤65 Non-depressed $N = 72$ | CDI ≥65 Depressed $N = 20$ | Test statistic |
|---|---|---|---|
| Age in years mean (sd) | 14.71 (2.6) | 14.59 (2.3) | $p = 0.85$ |
| Gender *n* (%) | | | |
| Male | 29 (40.3) | 7 (35) | $\chi^2 = 0.798$, $df = 1$, |
| Female | 43 (59.7) | 13 (65) | $p = 0.44$ |
| Premorbid Hx *n* (%) | | | |
| Headaches/migraines | 6 (6.5) | 3 (3.2) | $p = 0.90$ |
| Learning issues | 5 (5.4) | 2 (2.2) | $p = 0.61$ |
| Mental health | 4 (4.3) | 2 (2.2) | $p = 0.66$ |
| Months from injury to depression screen mean (sd) | 7.1 (8.8) | 6.6 (7.5) | $t_{(84)} = -0.26$, $p = 0.79$ |
| Referred *n* (%) | | | |
| Acutely from ED/wards | 23 (32) | 5 (7) | $\chi^2 = 0.562$, $df = 2$, |
| Tertiary care | 33 (46) | 11 (15) | $p = 0.755$ |
| Post-concussion symptom scores – mean (sd) | | | |
| Time 1 ($N = 90$) | 7.06 (5.4) | 11.05 (5.3) | $t_{89} = 2.95$, $p = 0.004$** |
| Time 2 ($N = 51$) | 6.41 (5.4) | 8.27 (7.0) | $t_{59} = 1.62$, $p = 0.035$ |
| Time 3 ($N = 35$) | 6.1 (4.5) | 10.11 (6.03) | $t_{33} = 2.12$, $p = 0.041$* |
| Cause of injury *n* (%) | | | |
| Sport related | 30 (47) | 13 (65) | $\chi^2 = 8.97$, $df = 8$, |
| MVA | 8 (12.5) | 2 (10) | $p = 0.35$ |
| Falls/trips | 9 (14) | 4 (20) | |
| Other | 17 (26.5) | 1 (5) | |
| Multiple concussions *n* (%) | 31 (56) | 7 (35) | $t_{(89)} = -0.738$, $p = 0.463$ |
| Decrease in academic standing *n* (%) | 29 (37.6) | 12 (15.5) | $F = 5.71$, $df = 1$, $p = 0.024$* |
| Admitted to hospital *n* (%) | 21 (30) | 7 (35) | $\chi^2 = 0.181$, $df = 1$, $p = 0.67$ |
| Length of stay in hospital mean (sd) | 1.76 (1.2) | 6.14 (5.2) | $t_{(22)} = 3.33$, $p = 0.003$** |

*Significant at the 0.05 level.
**Significant at the 0.01 level.

**Table III.** Correlation matrix for the relationship among non-injury- and injury-related concussion variables.

| VVar | 1. Gender | 2. Age | 3. LoFU | 4. LOS | 5. #con | 6. PCSI 1 | 7. PCSI 2 | 8. PCSI 3 | 9. EPS1 | 10. EPS3 | 11. DAS | 12. ChildT | 13. ParT | 14. Adm Hosp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Gender | 1 | 0.257* | 0.111 | −0.237 | −0.039 | 0.173 | 0.090 | 0.123 | 0.079 | −0.152 | 0.212 | 0.136 | 0.119 | −0.153 |
| 2. Age | | 1 | −0.033 | 0.131 | 0.078 | 0.147 | 0.081 | 0.133 | 0.071 | 0.145 | 0.219 | 0.165 | −0.052 | 0.022 |
| 3. LoFU | | | 1 | 0.333 | 0.051 | −0.004 | 0.024 | 0.037 | 0.081 | 0.066 | 0.024 | −0.051 | 0.191 | −0.421** |
| 4. LOS | | | | 1 | 0.422* | 0.095 | −0.090 | 0.341 | 0.262 | 0.321 | 0.229 | 0.269 | 0.198 | – |
| 5. #con | | | | | 1 | 0.078 | 0.117 | −0.198 | 0.019 | 0.052 | 0.108 | 0.051 | 0.033 | −0.374** |
| 6. PCSI 1 | | | | | | 1 | 0.440** | 0.171 | 0.186 | 0.456** | 0.382** | 0.442** | 0.304** | −0.253* |
| 7. PCSI 2 | | | | | | | 1 | 0.346* | −0.056 | 0.365* | 0.540** | 0.200 | 0.438** | −0.255 |
| 8. PCSI 3 | | | | | | | | 1 | −0.244 | 0.471* | 0.325 | 0.602** | 0.601** | 0.034 |
| 9. EPS1 | | | | | | | | | 1 | 0.231 | 0.187 | 0.188 | 0.009 | −0.180 |
| 10. EPS3 | | | | | | | | | | 1 | 0.502** | 0.483** | 0.146 | −0.062 |
| 11. DAS | | | | | | | | | | | 1 | 0.431* | 0.406** | −0.293* |
| 12. CDIT-Child | | | | | | | | | | | | 1 | 0.210 | −0.068 |
| 13. CDIT-Par | | | | | | | | | | | | | 1 | 0.077 |
| 14. Adm Hosp | | | | | | | | | | | | | | 1 |

LoFU = length of follow up, LOS = length of stay in hospital, #con = number of concussions, PCSI = post-concussive symptoms inventory score (time 1–3), EPS1 = experienced prolonged symptoms for 1 month, EPS3 = experienced prolonged symptoms for 3 months, DIAS = decrease in academic standing, CDIT-child = CDI T score recorded by child, CDIT-par = CDI T score recorded by parent, Adm Hosp = Admitted to hospital.
* is significant at the 0.05 level (2-tailed).
** is significant at the 0.01 level (2-tailed).

**Table IV.** Logistic regression predicting likelihood of depression in concussion recovery.

| Variables | B | S.E. | Wald | *df* | Sig. | Exp(B) | 95% C.I. for EXP(B) Lower | Upper |
|---|---|---|---|---|---|---|---|---|
| Symptom score T-1 | 0.278 | 0.106 | 6.896 | 1 | 0.009 | 1.32 | 1.073 | 1.624 |
| Admitted to Hosp | 2.464 | 1.136 | 4.705 | 1 | 0.03 | 11.748 | 1.268 | 108.82 |
| Symptoms >3 mos | 1.619 | 1.202 | 1.814 | 1 | 0.178 | 5.05 | 0.478 | 53.312 |
| ≥2 concussions | 0.197 | 0.29 | 0.461 | 1 | 0.497 | 1.217 | 0.69 | 2.148 |
| Gender (ref male) | −0.847 | 0.825 | 1.054 | 1 | 0.305 | 0.429 | 0.085 | 2.16 |
| Constant | −6.533 | 2.136 | 9.356 | 1 | 0.002 | 0.001 | | |

* is significant at the 0.05 level (2-tailed).
** is significant at the 0.01 level (2-tailed).

concussion symptoms reported on the PCSI-Time 1 ($r$ = 0.442, $p < 0.01$) and Time 3 ($r$ = 0.602, $p < 0.01$) indicating a linear relationship.

### *Logistic regression results*

The results of the logistic regression analysis show that the full model using the five independent variables of gender, number of concussions, admission to hospital, PCSI Time 1 score and experiencing symptoms over 3 months was significant ($X^2$ (5) = 18.55, $n$ = 71, $p < 0.002$). This means that the odds for children to have a positive depression score at a mean time of 6 months after concussion is associated with these five variables (see Table 3). The model correctly classifies 81.7% of cases. The Nagelkerke $R$-squared value of 0.357 indicates the model fits the data well. Table 3 presents the standardized coefficient beta, Wald statistic and significance as well as the odds ratios (OR) and 95% confidence intervals for the variables in the model. The strongest predictors in the model were high PCSI scores (standardized coefficient beta = 0.278, $p$ = 0.009) and admission to hospital (standardized coefficient beta = 2.464, $p$ = 0.030). Admission to hospital with an OR of 11.75 means that the odds that a child had a high depression score (T ≥65) increased by a factor of 11 if the child was admitted to hospital compared to those who were not admitted. The OR for early PCSI is 1.32, which indicates that for every one point increase in symptom scores (1 additional symptom), the odds of being depressed increase by a factor of 1.32.

Length of hospital stay was a variable that could not be used in the multivariate model because of the potential for over-fitting due to the small sample as only seven children had a stay over 24 hours. We did a univariate analysis using length of hospital stay to predict depression and found it to be significant $X^2$ = 8.06, $p < 0.005$ (standardized coefficient beta = 0.447, $p$ = 0.033). This single variable increased classification accuracy by 17% and has an OR of 1.56 indicating that for every extra day of stay in hospital, the likelihood of depression increased by a factor of 1.5.

## Discussion

In this prospective cohort of children and youth with concussion, we found the incidence of depression to be above that found in community samples cited in the literature and in standardized tests, which report a prevalence of 8–11% in this age group [24,25,49]. Twenty-two per cent of children self-reported significant depressive symptomatology, an average of 6 months following their injury. Youth in our study did report some premorbid histories of headache/migraine (9%), learning issues (7%) and mental health issues (7.5%); yet, none of these were significantly associated with ratings of post-concussion depression. Five predictors, sex, number of concussions, admission to hospital, PCSI score and experiencing prolonged symptoms explained 36% of the variance in depression scores.

Our prevalence of 22% is congruent with other published studies that report an increase in depression after mild-to-moderate TBI ranging from 11% to 26% [34,33] as well as findings of depression in other chronic medical conditions

including chronic pain, post-traumatic stress disorder, epilepsy and soft tissue injuries [28,50]. Our sample had a higher representation of girls who reported more symptoms than the larger dataset and 70% of the sample reported ongoing symptoms over 3 months. Girls are known to be at greater risk for more symptoms, neurocognitive changes and prolonged recovery [51,52]. It may be that the chronicity of symptoms experienced by the youths in this study contributed to the prevalence of depressive symptoms.

The findings of increased rates of depression after concussion are contradicted by a recent study conducted by Smyth et al. [35] who evaluated depression and pre-injury life stressors 1–3 years after injury and found only 3% of their sample had depression. Although this was also a concussion cohort, differences between the samples such as numbers of children admitted to hospital, sex distribution and the differences in timing of the depression evaluation (1–3 years after injury) in addition to the cross-sectional study design may explain the disparate results.

Other factors frequently hypothesized to be associated with depression including age, sex, cause of injury and the total number of head injuries had no significant relationship individually with depression in this study. These results were curious as sex in the general population of depressed adolescents has distinct differences with a 2:1 ratio of girls to boys into adolescence and adulthood [23,50]. Covassin, Elbin, Larson and Kontos also found no sex differences on depression scores after concussion in high school and collegiate athletes [53]. It is unclear whether there is a mediating effect of concussion in boys that equalizes the depression outcome between the sexes. Rates of depression in adolescents are known to be double those seen in younger children [54,55], yet our results were insignificant for age. This sample, however, had only twenty children in the 7–12 age group, which may have resulted in a type II error with not enough statistical power to show a true difference.

Evidence has also shown an association between multiple concussions and self-reported depression in retired adult football players [37]. Our data did not reflect these findings in children. Multiple concussions have been shown to predict prolonged symptoms, and time between concussions is a factor in recovery [56]. Neither prolonged symptoms nor depression was associated with multiple concussions in our data. Although 40% of the sample had two or more concussions, a larger sample size may have had the power to detect differences especially in the small groups of children with three, four and five injuries.

Although the study findings contribute to debate in the literature about the mechanism of the development of post-concussion depression, there are no clear causal relationships. On the one hand, damage to the brain, combined with other biological vulnerabilities (inherited traits of learning disabilities, temperament, etc.) is thought to provide a neurobiological susceptibility to depression [57]; on the other hand, stress (loss of meaningful activity, trauma, and family factors) can also influence the development of depression [58]. In our study, admission to hospital and length of stay increased the likelihood of showing elevated depressive symptoms in the first year after a concussive injury; however, this by itself is not conclusive. Although hospitalized youth may represent a subset of children who have a more severe injury, tentatively providing support to a neurobiological process leading to depression outcomes [59], hospitalization itself is very stressful which may trigger more anxiety and depression from environmental factors and explain the higher rates of depression after concussion found in studies using hospitalized samples [33,34]. In fact, our sample showed that most of the children were hospitalized for longer periods because of other injuries in addition to the concussion (spinal, musculoskeletal, etc.). These injuries themselves would be very stressful and lead to loss and uncertainty, which has been associated with depression. Other factors associated with a high depression score in our data were academic difficulties and experiencing symptoms over 3 months in duration, which both create a great amount of stress in the youth.

One of the most stressful activities post concussion is returning to school [60]. Thirty per cent of children recovering from concussion have reported school absence and dropping grades [61,62]. We found a significant relationship between a decrease in academic standing and depression scores. Our assessment of declining academic performance, while not objective, does capture parent and child perception of post-concussive school problems, and these findings as well as prolonged school absence may indicate that the child is depressed or at risk for becoming depressed. On the other hand, depression could very well precede a decrease in academic standing. Although the direction of this relationship remains unclear, school performance is worthy of attention for signalling potential poor outcomes.

Prolonged recovery from concussion was also moderately associated with depression in our sample and in our depression prediction model, a child with symptoms over 3 months had a 1.2-fold increased odds of being depressed even when accounting for all other variables.

Significant depressive symptoms can predispose youth to depression in subsequent years and later into adulthood [63]. Once a depressive episode has resolved, deficits in academics and social relationships remain making the developmental cost of depression in childhood and adolescence very high [21]. It is therefore vital to identify those children who may be susceptible to depression early in their recovery post concussion. Based on our results, we recommend that screening for depression in this vulnerable population should be a regular part of follow up, particularly for those who are admitted to hospital, have high symptom scores, experience protracted symptoms or are experiencing academic failure. Because we were unable to follow all children from inception, timing of depressive symptoms is an unknown. Longitudinal studies in adults have reported depression diagnosis early after injury [29,64]. In our study, significant depressive symptoms were reported at a mean of 6 months after injury, which may not represent the natural history of onset. Screening for depression should occur in the first weeks to months post concussion with further research needed to determine the optimal time period. Early identification might lead to timely provision of management strategies to prevent the effects of depression.

### Limitations

There are several limitations to this study. This research would have benefitted from a non-specific injury control group to determine if the cause of depressive symptoms was the concussion or the process of being injured in another way.

Our subset of data did differ from the larger dataset as 70% of the sub-sample had symptoms more than 3 months after their injury compared to 52% in the larger dataset, which suggests that

this subset of children seems to have more complex recovery patterns than previously seen. This is most likely a reflection of the increasingly specialized nature of the clinic attracting more complex referrals and may have inflated depression rates. Referral bias may also have been introduced due to the tertiary nature of this clinic. Although referrals were from a variety of sources, 50–60% were from other hospitals and community physicians, which suggests that these children may have been more chronic in their recovery patterns when referred. As a result of these factors and higher rates of girls and sport-related injuries, this sample may not be representative of concussions in the general population of the 8–18-year-old age group. However, the sample does include the spectrum of concussion recovery trajectories and provided a unique opportunity to examine a protracted symptom group. The clinical nature of the database resulted in some inconsistencies in data collection as children did not return for follow-up or information was not obtained, which means there were missing data over time. This may have resulted in a lack of power to detect difference between those with depression scores and those without and also may have limited the model building in predicting depression.

## Conclusion

Depression in the first year after childhood concussion is not a rare occurrence. Prevalence of depression during concussion recovery could be up to 2–4 times greater than that reported for childhood depression in published population data. This study adds to the knowledge regarding the risk of depression in youth recovering from concussion and some of the factors that play a role in increasing that risk. Children with a history including admission to hospital, high initial symptom scores and prolonged symptoms over 3 months should be followed closely with vigilance for the development of depressive symptoms.

## Declaration of Interest

The authors report no declarations of interest.

## Note

1. The word concussion in this article will be used to denote the spectrum of a range of concussive injuries and mild traumatic brain injuries.

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