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# Epidemiology of Postconcussion Syndrome in Pediatric Mild Traumatic Brain Injury



**WHAT'S KNOWN ON THIS SUBJECT:** There is much disagreement as to whether PCS can be attributed to a brain injury or other factors such as trauma alone, preexisting psychosocial problems, or medicolegal issues.



**WHAT THIS STUDY ADDS:** This study investigated PCS in a large pediatric population. The results supported the validity of PCS and indicated that a child with PCS who is still symptomatic 100 days after mTBI has a 40% likelihood of remaining symptomatic for the following month.

## abstract

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**BACKGROUND:** Much disagreement exists as to whether postconcussion syndrome (PCS) is attributable to brain injury or to other factors such as trauma alone, preexisting psychosocial problems, or medicolegal issues. We investigated the epidemiology and natural history of PCS symptoms in a large cohort of children with a mild traumatic brain injury (mTBI) and compared them with children with an extracranial injury (ECI).

**METHODS:** This investigation was a prospective, consecutive controlled-cohort study of 670 children who presented to a tertiary referral emergency department with mTBI and 197 children who presented with ECI. For all participants, data were collected by use of a telephone interview of a parent 7 to 10 days after injury. If a change from preinjury symptoms was reported by a parent, follow-up continued monthly until symptom resolution. Outcomes were measured by using the Post Concussion Symptom Inventory, Rivermead Postconcussion Symptom Questionnaire, Brief Symptom Inventory, and Family Assessment Device.

**RESULTS:** There was a significant difference between the mTBI and ECI groups in their survival curves for time to symptom resolution (log rank [Mantel-Cox] 11.15,  $P < .001$ ). Three months after injury, 11% of the children in the mTBI group were symptomatic (13.7% of children older than 6 years) compared with 0.5% of the children in the ECI group. The prevalence of persistent symptoms at 1 year was 2.3% in the mTBI group and 0.01% in the ECI group. Family functioning and maternal adjustment did not differ between groups.

**CONCLUSIONS:** Among school-aged children with mTBI, 13.7% were symptomatic 3 months after injury. This finding could not be explained by trauma, family dysfunction, or maternal psychological adjustment. The results of this study provide clear support for the validity of the diagnosis of PCS in children. *Pediatrics* 2010;126:e374–e381

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### KEY WORDS

mild traumatic brain injury, children, cerebral concussion, postconcussion syndrome, epidemiology, outcome

### ABBREVIATIONS

ED—emergency department  
mTBI—mild traumatic brain injury  
PCS—postconcussion syndrome  
LOC—loss of consciousness  
REDIS—Regional Emergency Department Information System  
PCSI—Post Concussion Symptom Inventory  
RPQ—Rivermead Postconcussion Symptoms Questionnaire  
GFS—General Functioning Scale  
FAD—Family Assessment Device  
BSI—Brief Symptom Inventory

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Head injuries significant enough to require medical attention in the emergency department (ED) occur in 150 to 400 per 100 000 people, and mild traumatic brain injury (mTBI) accounts for 75% to 85% of these injuries.<sup>1,2</sup> Children have the highest incidence of mTBI; in the United States mTBI it occurs 692 of 100 000 children younger than 15 years.<sup>2</sup> Investigators have recently found that mTBI is associated with serious long-term consequences.<sup>3</sup> Because 16% of children have had at least 1 head injury requiring medical attention by 10 years of age, mTBI is considered to be a significant public health concern.<sup>4</sup> Although there is widespread agreement that mTBI may be associated with significant neuropsychological problems, there is disagreement about whether these problems can be attributed to the brain injury itself.<sup>5</sup> Some researchers have suggested that preinjury factors (age, alcohol abuse, education, and neuropsychiatric history), as well as factors that occur after injury (eg, stress and litigation) significantly contribute to the disabilities suffered by patients with mTBI.<sup>6,7</sup>

Postconcussion syndrome (PCS), the most common entity to be diagnosed in people who have suffered TBI, is a constellation of physical, cognitive, emotional, and behavioral symptoms. The prevalence of PCS after adult mTBI has been reported to vary from 11% to 64% depending on the diagnostic criteria used.<sup>8</sup> The *International Classification of Diseases, 10th Revision* code requires the presence of at least 3 of 8 symptom categories occurring within 1 month of the injury. Criteria of the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* require the presence of symptoms in at least 3 of 6 categories for at least 3 months after injury and evidence of neuropsychological dysfunction. The prevalence of persistent symptoms at

1 year is not known but is estimated to be <5%.<sup>5</sup> There is limited information on the prevalence and incidence of PCS in children. The few available study reports have included estimations that PCS occurs in 6% to 35% of children after TBI.<sup>9,10</sup> Despite the prevalence of PCS, doubt exists about the validity of this diagnosis because behavioral disturbances frequently occur in children after any injury and because factors present before injury and medicolegal concerns after injury may influence recovery.<sup>11–13</sup>

The purpose of this study was to determine the incidence of PCS after mTBI in children and to characterize the nature of PCS symptoms and document their natural history. We hypothesized that compared with children with ECI, children with mTBI would have a higher incidence of PCS symptoms and that these symptoms would persist longer.

## PATIENTS AND METHODS

This study was a prospective, consecutive-cohort epidemiologic study of PCS symptoms after mTBI in children (aged 0–18 years) who were treated at the ED of a tertiary-care children's hospital with a catchment population of 1.3 million. This study was approved by the University of Calgary Conjoint Health Research Ethics Board.

### mTBI Group

mTBI was defined as an admission Glasgow Coma Scale score of 13 to 15, loss of consciousness (LOC) or altered mental state that lasted <20 minutes, absence of focal neurologic deficits, and posttraumatic amnesia that lasted <24 hours.<sup>14</sup> The definition of mTBI is somewhat controversial in younger children, in whom it can be difficult to assess an altered mental state and period of amnesia. Therefore, any child with a mild head injury without clear evidence contradicting

the above criteria was included in the study. Children with simple scalp lacerations, facial injuries/fractures, or superficial injuries who did not display neurobehavioral change were excluded. mTBI children who had any ECI were also excluded.<sup>14</sup>

### Severity of Concussion

In all patients with mTBI, the concussion injury was categorized according to severity by a neurologist (Dr Barlow), who used the information provided to ED staff regarding LOC, amnesia, and symptoms and signs after the injury. The American Congress of Rehabilitation Medicine criteria for mild traumatic brain injury were used.<sup>14,15</sup> Each mTBI was subcategorized on the basis of symptoms, according to a scale of A through F, with equivalent concussion severity grades (Table 1). These subcategories have been used in previous investigations.<sup>16,17</sup> Very young children with behavioral change such as "poor feeding" or "fussy" but without classic symptoms of concussion such as headache, vomiting, or LOC were included in category A.

### Case Identification

Between November 2005 and January 2008, 78% of children in this urban area seen in EDs with ICD codes for intracranial injuries, including concussion, were seen at this regional ED. The Regional Emergency Department Information System (REDIS) database was used to identify children. The entries categorized as "head injury," "central nervous system," "traumatic injury," or "other" together with the injury descriptions were searched. All REDIS cases were reviewed by a neurologist experienced in TBI (Dr Barlow). The parents of 1264 children with mTBI were contacted 7 to 10 days after injury, and 670 children participated in the study. No differences in age, gender, LOC, or disposition after the ED

**TABLE 1** Subcategories of mTBI and the Characteristics of Children in Each Subcategory<sup>16,17</sup>

mTBI Category	Amnesia	LOC	Symptoms	Neurologic Findings <sup>a</sup>	Concussion Grade <sup>b,c</sup>	% of Group	Age, Mean (SD), y
A <sup>b</sup>	No	No	No	No	1	20.2	4.6 (4.7)
B	No	No	Slight <sup>c</sup>	No	1	18.4	8.2 (5.3)
C	No	No	Pronounced	Yes	2	29.4	7.5 (5.4)
D	Yes	No			2	8.4	13.1 (3.6)
E		1 s–1 min			3	12.6	10.2 (5.4)
F		2 s–20 min			3	4.4	12.6 (4.7)

There was insufficient information for accurate categorization of 6.4% of the children.

<sup>a</sup> Not fully awake and/or focal neurological deficit.

<sup>b</sup> Included infants described as “fussy,” “irritable,” or “poor feeding.”

<sup>c</sup> Slight headache, dizziness, nausea, and/or vomiting.

visit were found between participants and nonparticipants.

### ECl Group

Children with ECl identified through REDIS were contacted ( $n = 324$ ) and 37% took part in the study ( $n = 120$ ). The participation rate was lower for the ECl group ( $P < .01$ ). No differences in age, gender, or disposition after ED visit were found between participants and nonparticipants. Only 2 participants recruited via this method returned the questionnaires that measured family functioning and maternal adjustment. Therefore, a subgroup was identified through the fracture clinic who completed these questionnaires during their clinic visit ( $n = 77$ ). Children with cranial injury were excluded.

### Measures

The Post Concussion Symptoms Inventory (PCSI) is a standardized questionnaire that consists of 26 symptoms and provides an overall rating of symptoms based on parent report. It has 6 specific domains: physical, fatigue, cognitive, affective, amnesia, and sleep, and has a high level of internal consistency,  $\alpha = 0.93$ .<sup>18</sup> Individual scores for each symptom (0–4), a total symptom score (0–104), and a “degree of difference from preinjury” score (0–4) were obtained. Symptom scores of 3 or 4 were classified as “moderate to severe” symptoms and scores of 0 to 2 as “mild.” A change of 2

or more points in any symptom was considered clinically significant.

The Rivermead Postconcussion Symptoms Questionnaire (RPQ) is a commonly used measure of the severity of symptoms after mTBI, although it does not meet modern psychometric standards.<sup>19</sup> This questionnaire addresses 16 postconcussion symptoms that are similar to those addressed in the PCSI. The total and scores on 2 domains (cognitive and emotional-somatic) were calculated.<sup>19</sup>

Children were considered to be symptomatic if parents reported a score of 1 to 4 for the following statement: “In general, to what degree is your child acting differently than before the injury (not acting like him/herself), where 0 is no difference and 4 is a major difference?” and reported that at least 1 symptom showed an increase of 2 or more points on the PCSI.

Symptom resolution was defined as the point at which parents reported no change from before the injury and the scores for all symptoms were back to or below preinjury levels. Time to symptom resolution was calculated as the number of days between the injury and the day after the last telephone contact at which the child was symptomatic.

The 12-item General Functioning Scale (GFS) of the McMaster Family Assessment Device (FAD) was used as a summary measure of family functioning.<sup>20</sup>

This questionnaire was completed by the mothers of patients 1, 6, and 12 months after injury.

The Brief Symptoms Inventory (BSI) was used to assess maternal psychological adjustment at 1, 6, and 12 months after injury. The BSI is a widely used 53-item, self-report questionnaire of psychiatric symptoms with well-documented reliability and validity.<sup>21</sup> It has 2 global measures of psychological symptoms: the mean Global Severity Index which is a sensitive indicator of a respondent’s distress level; and the mean Positive Symptom Distress Index which is a marker of intensity of symptoms.

At enrollment, the parents completed the PCSI. They were first asked to complete the questionnaire in terms of the symptoms the child displayed before the injury (preinjury symptoms) and then complete the questionnaire on the basis of symptoms present during the last few days (postinjury symptoms). If the child was symptomatic, a follow-up telephone call was initiated in 2 weeks and symptoms were reviewed by using the PCSI. Follow-up calls continued at monthly intervals thereafter until symptom resolution.

### Statistical Analysis

All analyses were performed by using SPSS 17.0 (SPSS Inc, Chicago, IL). Means, SDs, and ranges were used to describe the sample. The Kolmogorov-Smirnov test was used to test for normal distribution of the data. In cases in which data were not normally distributed, nonparametric tests (Pearson’s  $\chi^2$  test, Mann-Whitney  $U$  test) were used to conduct group comparisons. Effect sizes for Mann-Whitney  $U$  test values were calculated by dividing the obtained  $U$  value by the product of the 2 sample sizes.<sup>22</sup> Between-group comparisons of demographic, injury, and past medical details were made by using Pearson  $\chi^2$  cross-tabulations. For

**TABLE 2** Demographic and Injury Characteristics in the mTBI and ECI Groups

	mTBI (N = 670)	ECI (N = 197)	P
Age			.009 <sup>a</sup>
Mean (SD), y	>7.62 (5.61)	>9.44 (4.4)	
Range, y	0.01–17.9	0.17–17.79	
Male gender, %	57.5	46.7	.074
Total family income, median (SD)	\$88 960 (\$26 385)	\$90 570 (\$30 235)	.711
After-tax income, median (SD)	\$74 313 (\$19 304)	\$75 729 (\$21 257)	.654
Admission to hospital, %	6.4	22.4	.002 <sup>a</sup>
LOC, %	10.7	0	.001 <sup>a</sup>
Mechanism of injury, %			
Fall	51.4	41.6	.045 <sup>b</sup>
Sports related	25.0	44.2	.001 <sup>a</sup>
Unknown	12.3	9.1	.473
Motor vehicle accident	2.0	2.6	.078
Assault	1.3	.0	.616
Other	8.0	2.6	.078
Abbreviated Injury Severity score			<.001 <sup>a</sup>
n	375	197	
1, %	78.5	62.9	
2, %	20.7	35.3	
3, %	0.8	1.8	
Time after injury of PCSI before injury, median (SD), d	15.85 (11.6)	16.55 (14.7)	.63

<sup>a</sup>  $P < .01$ .<sup>b</sup>  $P < .05$ .

normally distributed data (ie, FAD, BSI), *t* tests and analysis of covariance were used to examine group differences. Symptom-free survival was calculated by using Kaplan-Meier log-rank analysis. Participants were censored if they were lost to follow-up, withdrew from the study, or had another injury. Multivariate logistic regression was used to examine associations of age, injury severity, and symptom status.

## RESULTS

The demographic and acute-injury details for the mTBI and ECI groups are shown in Table 2. Children in the ECI group were older than those in the mTBI group ( $P < .001$ ). Falls were associated with younger age ( $P < .001$ ). In the mTBI group LOC was reported in 10.7% of children, and falls were associated with older age ( $P < .001$ ). A higher proportion of children in the ECI group (22.4% vs 6.4%) were admitted to the hospital ( $P = .04$ ). The percentages of children lost to follow-up were 13% in the mTBI group and 10% in the ECI group.

## Symptoms Before Injury

PCSI data on symptoms present before injury were collected 15.85 (SD: 11.6) days after the injury in the mTBI group and 16.55 (SD: 14.7) days after injury in the ECI group ( $P = .63$ ). Before injury, 56% of children in the mTBI group and 55.4% of children in the ECI group were reported to have at least 1 symptom according to results of the PCSI. The most common moderate-to-severe symptoms reported in the mTBI group were irritability (9%),

difficulty falling asleep (8%), and headaches (1%). The most common moderate-to-severe symptoms in the ECI group were irritability (4%), difficulty falling asleep (13%), sensitivity to noise (5%), and headaches (3%). The total symptom scores for symptoms before injury did not differ between groups ( $P = .98$ ).

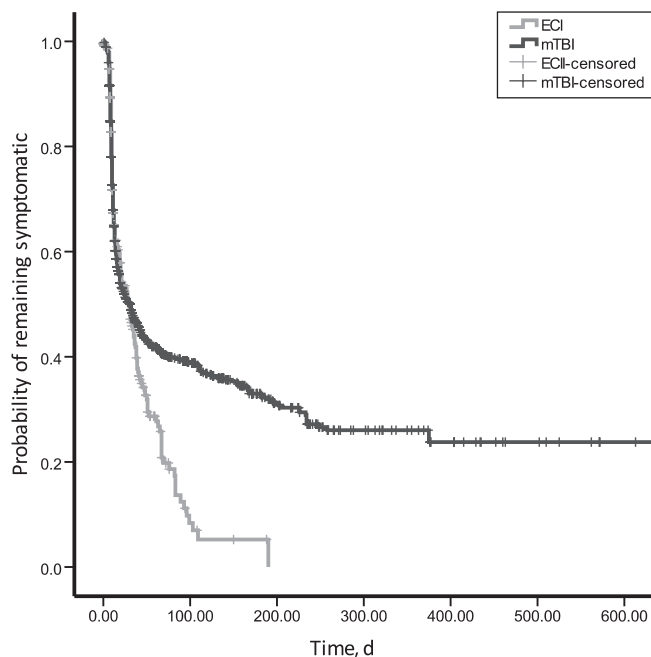
## Outcome

In the first month after injury, 58.5% and 38.5% of children with mTBI and ECI were symptomatic, respectively (Table 3). As shown in Fig 1, the probability of a child in the mTBI group remaining symptomatic was significantly higher than for a child in the ECI group (log-rank [Mantel-Cox] 11.149;  $P < .001$ ). If a child with mTBI was symptomatic at 100 days, for example, the child would have a 40% likelihood of remaining symptomatic compared with a 15% likelihood for a child with ECI. Three months after injury, 11% of children were symptomatic in the mTBI group compared with 0.5% in the ECI group. Three months after injury in children older than 6 years, 13.7% of the mTBI group and 1% of the ECI group were symptomatic. The most common symptoms that had increased from before injury to 1 month after injury were “fatigue” (79%), “more emotional” (60%), “irritability” (58%), and head-

**TABLE 3** RPQ and the PCSI Scores in Children With mTBI or ECI 1 and 3 Months After Injury

Time After Injury	mTBI		ECI		U	P	Effect Size
	Mean (SD)	Range	Mean (SD)	Range			
1 mo (mTBI, n = 670; ECI, n = 197)							
PCSI total	11.15 (15.09)	0–73	7.62 (10.87)	0–57	17 519.0	.01	0.133
RPQ total	11.02 (10.65)	0–50	6.09 (7.76)	0–38	10 807.5	<.001	0.082
Emotional-somatic	9.72 (9.24)	0–42	5.11 (6.30)	0–32	11 135.0	<.001	0.084
Cognitive	1.80 (2.67)	0–11	.99 (1.92)	0–9	14 472.5	<.001	0.110
3 mo (mTBI, n = 105; ECI, n = 25)							
PCSI total	14.25 (16.34)	0–64	5.08 (7.96)	0–32	514.0	<.001	0.196
RPQ total	13.33 (10.46)	0–41	3.31 (5.10)	0–20	483.5	<.001	0.184
Emotional-somatic	10.76 (7.94)	0–30	2.75 (4.08)	0–15	460	<.001	0.175
Cognitive	2.30 (3.16)	0–12	0.52 (1.26)	0–4	851	<.001	0.324

More symptoms were reported for children with mTBI than children with ECI group 1 and 3 months after injury, as demonstrated by higher scores on the RPQ and PCSI.



**FIGURE 1** Survival curves demonstrating persistence of symptoms in children in the mTBI group compared with those in the ECI group (log rank [Mantel-Cox] = 11.15;  $P < .001$ ).

aches (58%). The total RPQ scores correlated significantly with the total PCSI scores,  $r = .95$ ,  $P < .001$ .

The percentage of children who met *International Classification of Diseases, 10th Revision* criteria for PCS was 82% of those in the mTBI group who were symptomatic 3 months after injury. This result suggests that 9% of all children with mTBI ( $n = 60$ ) had PCS 3 months after injury.

Significant differences were found between groups for the child's age at injury ( $P = .009$ ). Posthoc comparisons revealed that the asymptomatic mTBI group was younger than the symptomatic mTBI group ( $P < .05$ ). When mTBI severity was considered, the probability that a child would remain symptomatic was significantly associated with the severity of the injury; children with more severe mTBI displayed a significantly higher probability of remaining symptomatic over time (log-rank [Mantel-Cox] = 85.88;  $P < .001$ ) (Fig 2). Children older than 6 years were also more likely to remain symptomatic

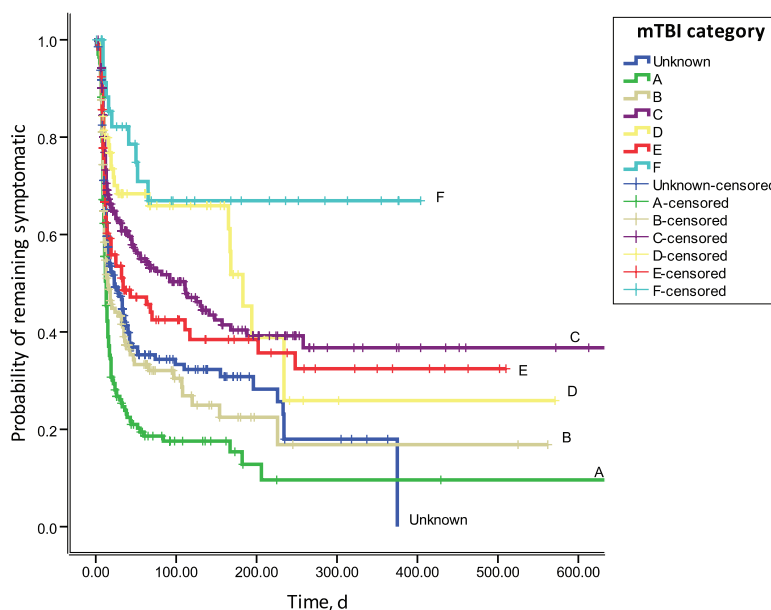
than younger children (log-rank [Mantel-Cox] = 51.64;  $P < .001$ ) (Fig 3). Multivariate logistic regression was used to examine the associations between injury severity, age, and symp-

tom status. Results revealed that only injury severity was associated with symptom status (Wald = 5.689;  $P = .017$ ).

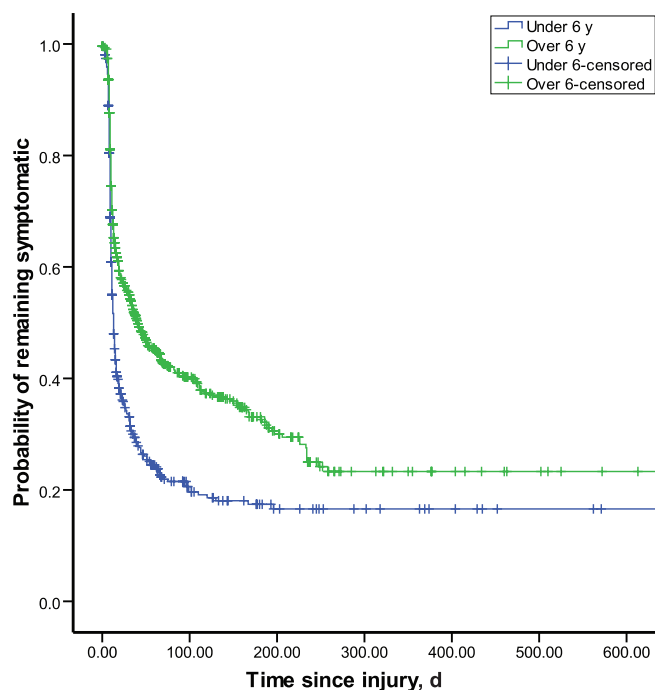
Fifteen children with mTBI (2.3%) remained symptomatic for longer than 12 months. In 6 of these children significant premorbid psychological stressors were subsequently diagnosed, and 2 had posttraumatic stress disorder after motor vehicle accident (diagnosed by a psychiatrist). Nine children had chronic posttraumatic headache. In 2 cases further neurologic assessment of the child was refused.

### BSI and FAD

The initial BSI and FAD responses for each group were compared. The mean GFS on the FAD was similar in both groups; symptomatic mTBI mean = 1.70 (SD: 0.44) and ECI group mean = 1.65 (SD: 0.43) ( $P = .55$ ). The BSI scores did not reveal significant differences between groups: the mean Global Severity Index (a sensitive indicator of respondent's distress level) was 0.43 (SD: 0.06) in the mTBI group and 0.41



**FIGURE 2** Survival curves demonstrating that symptoms are more likely to persist in more severe mTBI injury categories (log rank [Mantel-Cox] = 85.88;  $P < .001$ ).



**FIGURE 3**

Survival curves demonstrating that symptoms are more likely to persist in children older than 6 years (log rank [Mantel-Cox] = 51.64;  $P < .001$ ).

(SD: 0.10) in the ECI group ( $t = 0.12$ ;  $P = .91$ ). The mean Positive Symptom Distress Index) was 1.28 (SD: 0.74) in the mTBI group and 1.57 (SD: 0.13) in the ECI group ( $t = -1.9$ ;  $P = .06$ ). The time to complete these questionnaires differed between the 2 groups: mTBI, 49 days (SD: 19), and ECI, 21 days (SD: 14), ( $t = 7.26$ ,  $P < .001$ ). The inclusion of time as a covariate had no effect on the significance of the above-mentioned findings (GFS:  $P = .653$ ; Global Severity Index:  $P = .659$ ; Positive Symptom Distress Index:  $P = .089$ ).

## DISCUSSION

This study was one of the largest detailed, prospective, population-based studies of children after mTBI. The study results demonstrated a definite increase in the duration of PCS symptoms in children with mTBI compared with children with ECI. Eleven percent of children in the mTBI group were symptomatic 3 months after injury compared with 0.5% of the ECI group. This difference was not attributable to

group differences in injury status, age, family dysfunction, or maternal adjustment.

Results of a few other studies of children with PCS have revealed an early decrease in functioning that largely resolved by 2 to 3 months after injury.<sup>23–25</sup> Our study results are in keeping with those of a recent study in which investigators observed different trajectories of postconcussive symptoms in children with mTBI compared with children with orthopedic injuries.<sup>26</sup> In addition, our results were similar to those of Ponsford et al, who found that almost 14% of school-aged children with PCS were symptomatic 3 months after injury.<sup>27</sup> The different trajectories of postconcussive symptoms in children with mTBI compared with children with ECI may be attributable to differences in information provided to families after a child suffers an mTBI. At our hospital, all families were given information in the ED about how to monitor their children after a head in-

jury. Therefore, these parents may have expected difficulties and this expectation may have influenced their symptom reports.

One strength of this study relative to many other studies of children with mTBI was that young children were not excluded. Therefore, our results more accurately reflect the population of children with mTBI who are seen in an ED and may show evidence of PCS.<sup>16,25,26</sup> However, because of the difficulty in identifying mTBI in young children, the inclusion of these children in this study raises the possibility that our sample may have included children whose symptoms were overestimated or underestimated. The exclusion of children with extracranial injury from the mTBI group may have restricted the prevalence of more severe mTBI in this sample. Other potential weaknesses of the study include the use of the American Congress of Rehabilitation Medicine classification of mTBI, particularly with young children.<sup>28–30</sup> Indeed, we found that older children were more likely to have PCS, although this finding seemed to be largely accounted for by injury severity. Other factors that may account for this difference include the possibility that PCS is age dependent, the higher proportion of young children who presented with minor injuries, the tendency of young children to have symptoms such as poor feeding or being fussy rather than classical PCS symptoms, and the lack of validation for young children of questionnaires used to assess PCS.

It is possible that reporting bias was introduced by the retrospective collection of data on symptoms that were present before injury. We found, however, that symptoms were commonly present before injury in both groups of children. This finding is in keeping with reported findings of other studies, in which PCS symptoms were frequently found in populations of healthy chil-

dren and of children with clinical conditions (eg, chronic pain or depression).<sup>5,31</sup> Because the usefulness and specificity of PCS as a diagnosis has been debated, we tried to avoid having preconceived ideas about what was required for a diagnosis of PCS. The criteria used to determine whether a child was kept under surveillance were liberal (ie, the parent thought the child was “different” and there was an objective increase in at least 1 symptom). However, we found that 82% of the symptomatic children 3 months after injury had complaints in at least 3 of the 6 symptom domains of the PCSI.

Preexisting factors such as family dysfunction, psychiatric illness, and maternal psychological adjustment have been implicated as important in the persistence of postconcussive symp-

toms.<sup>10,27</sup> In our study we found no difference in the BSI and FAD scores between groups. Although in the ECI group the available BSI and FAD data were mostly from children recruited from fracture clinics, early symptoms are not likely to be attributable to differences in maternal psychological adjustment and family dysfunction. This finding is consistent with some recent research results that indicate that family burden and parental adjustment are similar in children with mTBI and control children with orthopedic injuries.<sup>32</sup>

## CONCLUSIONS

To our knowledge, this is the first study to report a reliable estimate of the prevalence of PCS symptoms 1 year after injury (2.3%). Therefore, we can reassure children with mTBI and their families that these symptoms are

likely to resolve within 12 months after injury. School-aged children with mTBI involving an LOC may have a more protracted course of PCS symptoms. Although long-term outcomes are good, 14% of school-aged children with mTBI have significant morbidity for several months. Provision of proper education and reassurance soon after injury can reduce postconcussive symptoms in adults, but as yet there is strikingly little evidence to guide the management and treatment of PCS in children.<sup>33–35</sup> The impact of PCS on school performance and social functioning at this critical time in development is likely to be significant and is worthy of future research.

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