abstract

OBJECTIVE: To test the hypothesis that children with a previous history of concussion have a longer duration of symptoms after a repeat concussion than those without such a history.

METHODS: Prospective cohort study of consecutive patients 11 to 22 years old presenting to the emergency department of a children’s hospital with an acute concussion. The main outcome measure was time to symptom resolution, assessed by the Rivermead Post-Concussion Symptoms Questionnaire (RPSQ). Patients and providers completed a questionnaire describing mechanism of injury, associated symptoms, past medical history, examination findings, diagnostic studies, and the RPSQ. Patients were then serially administered the RPSQ for 3 months after the concussion or until all symptoms resolved.

RESULTS: A total of 280 patients were enrolled over 12 months. Patients with a history of previous concussion had a longer duration of symptoms than those without previous concussion (24 vs 12 days, P = .02). Median symptom duration was even longer for patients with multiple previous concussions (28 days, P = .03) and for those who had sustained a concussion within the previous year (35 days, P = .007) compared with patients without those risk factors. In a multivariate model, previous concussion, absence of loss of consciousness, age ≥ 13, and initial RPSQ score > 18 were significant predictors of prolonged recovery.

CONCLUSIONS: Children with a history of a previous concussion, particularly recent or multiple concussions, are at increased risk for prolonged symptoms after concussion. These findings have direct implications on the management of patients with concussion who are at high risk for repeat injuries. Pediatrics 2013;132:8–17

WHAT’S KNOWN ON THIS SUBJECT: Although concussion is increasingly being diagnosed in the pediatric population, little is known about what factors lead to prolonged postconcussive symptoms in children. In particular, the effect of previous history of concussion on recovery from a repeat injury is unclear.

WHAT THIS STUDY ADDS: Children with a history of previous concussion, particularly recent or multiple concussions, are at increased risk for prolonged symptoms after concussion. This suggests that repeat concussion, particularly within a vulnerable time window, may lead to longer duration of symptoms.

AUTHORS: Matthew A. Eisenberg, MD, John Andrea, BS, William Meehan, MD and Rebekah Mannix, MD, MPH
Division of Emergency Medicine, Boston Children’s Hospital, Harvard Medical School, Boston, Massachusetts

KEY WORDS
brain concussion, emergency medicine, pediatrics, postconcussion syndrome, traumatic brain injury

ABBREVIATIONS
ADHD—attention-deficit/hyperactivity disorder
ED—emergency department
LOC—loss of consciousness
mTBI—mild traumatic brain injury
RPSQ—Rivermead Post-Concussion Symptoms Questionnaire

Dr Eisenberg was responsible for study conception and design, data acquisition and analysis, and drafting and review of the article; Mr Andrea was responsible for data acquisition and analysis, and drafting and review of the article; Dr Meehan was responsible for study conception, study design, and article review; Dr Mannix was responsible for study conception, study design, data analysis, and article review; and all authors approved the final version of this manuscript.

doi:10.1542/peds.2013-0432
Accepted for publication Mar 27, 2013

Address correspondence to Matthew A. Eisenberg, MD, Division of Emergency Medicine, Boston Children’s Hospital, 300 Longwood Ave, Boston, MA 02115. E-mail: matthew.eisenberg@childrens.harvard.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding. Expenses related to use of research coordinators were paid by the Division of Emergency Medicine, Boston Children’s Hospital.
Animal models of mTBI offer a possible explanation for this variation, suggesting that both timing and number of injuries modify the effects of previous injury. In particular, several studies in rodents suggest that the effect of multiple concussions is cumulative, and that the time elapsed between concussions to allow for return of normal physiologic function may be the key to the course of recovery.

Despite this, no clinical study has characterized the vulnerable window during which repeat concussion results in worse outcome among children, or the critical number of injuries that confers increased risk of prolonged recovery. If reinjury within a window of vulnerability confers higher risk of long-term neurocognitive deficits, then abstinence from at-risk activities may ultimately improve outcomes. The objective of this study was to characterize the effect of previous concussion on recovery from concussion among children presenting to an ED. We hypothesized that those with a previous history of concussion would have a longer time to symptom resolution than those without such a history, and that those who sustained a concussion within the previous year would have a longer time to symptom resolution than those with more remote injuries.

**METHODS**

**Study Design**

We conducted a prospective cohort study of consecutive patients aged 11 to 22 years who presented to the ED of a tertiary care children’s hospital within 72 hours of a concussion from September 1, 2011, to August 31, 2012.

**Definition**

Concussion was defined as a blunt injury to the head resulting in either (1) alteration in mental status or (2) any of the following symptoms that started within 4 hours of the injury and were not present before the injury: headache, nausea, vomiting, dizziness/balance problems, fatigue, drowsiness, blurred vision, memory difficulty, or difficulty concentrating in the absence of indications for head imaging or without intracranial hemorrhage when imaging was obtained. Although there has been controversy regarding the definition of concussion for clinical research, we chose this broad definition so as to include both those who had alteration of consciousness and those who presented with typical postconcussive symptoms following a head injury.

Patients were excluded from the study if any of the following were present: (1) Glasgow Coma Score <13 on arrival to the ED, (2) coexisting skull or long-bone fracture, (3) coexisting injury to intra-abdominal or intrathoracic organ or spinal cord, (4) cognitive or developmental disability preventing patient from completing the questionnaire, or (5) involvement of either law enforcement or ED social workers for victims of an assault. These criteria were designed to distinguish postconcussive symptoms from symptoms related to other injuries or psychological stresses related to major trauma or assault.

**Primary Outcome**

The primary outcome was time to resolution of postconcussive symptoms assessed via the Rivermead Post-Concussion Symptoms Questionnaire (RPSQ), a 16-item concussion symptom inventory checklist. The RPSQ has been used extensively in both adult and pediatric studies of mTBI, shown a high degree of interrater and test-retest reliability, and been shown to be valid and unbiased in young children. The questionnaire was available to study participants in both English and Spanish. Patients were considered symptom-free when all inventories of the RPSQ were scored...
a 0 (symptom not present) or 1 (symp-
tom present at preinjury baseline). Patients
filled out the survey independently or with assistance of parents at
the discretion of the patient and family.

Enrollment and Consent
Study participants were enrolled dur-
ing their ED visit by trained research
 coordinators after informed consent
(and assent for patients <18 years)
was obtained. Eligible patients who
were not contacted during their ED visit
were offered enrollment the following
day if they were still within 72 hours of
the injury. On enrollment, patients
completed an electronic questionnaire
asking for demographic information
(including self-reported race and
 ethnicity), mechanism of injury, asso-
 ciated symptoms, such as loss of con-
 sciousness (LOC) and amnesia, relevant
 past medical history, and the RPSQ.
 Providers completed a questionnaire
with physical examination findings, di-
agnostic studies, and information on
interventions, disposition, and dis-
charge instructions.

Follow-up
An online follow-up questionnaire con-
taining the RPSQ was sent electronically
to patients 1, 2, 4, 6, 8, and 12 weeks after
their ED visit or until they met criteria
for symptom resolution. Patients who
reported resolution of symptoms were
prompted to provide the last date on
which symptoms occurred. Patients
with incomplete or inconsistent data
were called to resolve these issues.
Patients were considered lost to follow-
up if they failed to respond to 2 con-
secutive questionnaires. Study data
were collected and managed using REDCap (Research Electronic Data
Capture, Nashville, TN) electronic data
capture tools hosted at Boston Child-
ren’s Hospital.

Statistical Analysis
Statistical analysis was performed by
using PASW Statistics 18 (IBM SPSS
Statistics, IBM Corporation, Chicago, IL).
We estimated that 250 patients would
be required to demonstrate a 5-day
difference in time to resolution of
symptoms between those with and
without previous concussion, using
a 2-tailed $\alpha$ of 0.05 and power of 90%.
Data were analyzed by Student’s $t$-test
or Wilcoxon Rank Sum test as appro-
 priate. Our primary outcome, time to
symptom resolution, was assessed as
a continuous variable ranging from
0 to 90 days. Potential predictors that
were continuous in nature were di-
 chotomized before analysis according
to their median value. The only excep-
tion to this was age; 13 years or older
was chosen rather than the median as
a proxy for pubertal status.
In univariate analysis of time to symp-
tom resolution, Kaplan-Meier analysis
with log-rank tests of significance was
used to best account for censored data.
To adjust for confounders, we con-
structed a multivariate Cox regression
model using predictors with $P < .05$ on univariate screening. Where
Kaplan-Meier analysis was performed,
“median” refers to median survival
time (where “survival” signifies per-
sistence of symptoms), a measure that
takes into account expected duration of
symptoms for censored patients. Val-
ues were considered statistically sig-
nificant if $P < .05$. The institutional
review board approved this study be-
fore onset of data collection.

RESULTS
Study Population
A total of 302 patients were approached
for the study and 280 (93%) were en-
rolled over a 12-month period (Fig 1);
207 patients (74%) completed the
study, 28 (10%) completed at least 1
follow-up questionnaire but did not
complete the study, and 45 (16%) were
lost to follow-up. Nonwhite patients,
Hispanic patients and patients with
attention-deficit/hyperactivity disorder
(ADHD) were more likely to be lost to
follow-up (Table 1).

FIGURE 1
Flow sheet of included and excluded patients. GCS, Glasgow Coma Score; ICD-9, International Classi-
fication of Diseases, Ninth Revision.
Patient Presentation

Most patients (66.0%) were enrolled in the study on the day their concussion occurred, with 24.7% enrolled the following day, 7.2% enrolled 2 days later, and 1.7% 3 days later.

A majority of (63.8%) patients were injured playing a sport, with the most common sports being hockey (14%), soccer (9.4%), football (8.5%), and basketball (8.1%). The most common presenting symptoms (RPSQ score ≥ 2) were headache (85.1%), fatigue (64.7%), and dizziness (63.0%). An abnormal physical finding was noted in 10.6% of patients, with the most common abnormalities being altered gait or balance (4.3%) and altered mental status (2.4%). Among the 20.8% of patients who had neuroimaging performed, there were no abnormalities identified related to trauma. On discharge, 65.9% of patients were prescribed a period of cognitive rest, 92.4% were recommended to return to school, and 63.8% were advised to return to their primary care doctor, 45.5% in a sports concussion clinic, and 6.2% with another specialist.

Time to Recovery

Median time to symptom resolution and percentage of patients symptomatic 7, 28, and 90 days after the concussion are shown in Table 2. In univariate analysis, history of previous concussion (Fig 2A), age ≥13, initial RPSQ score >18, female gender, history of depression, absence of LOC, and abnormal neurologic examination on presentation were all predictive of a longer time to symptom resolution (Table 2). Among patients with a previous concussion, those who had a concussion in the past year had nearly 3 times the median duration of symptoms compared with those who had no previous concussion or whose most recent concussion occurred >1 year previous (Fig 2B). Similarly, patients with 2 or more previous concussions had more than double the median symptom duration compared with patients with 0 or 1 previous concussion (Fig 2C).

In the multivariate model, patients with a history of previous concussion, absence of LOC, age ≥13, and RPSQ score >18 had significantly longer symptom duration than patients without these risk factors (Table 3).

DISCUSSION

Our study demonstrates that previous concussion is predictive of a longer time to symptom resolution after pediatric concussion. Importantly, we found that the effect of previous concussion on symptom duration was strongly influenced by both the number of previous concussions and the time elapsed since the most recent previous concussion. Both study participants with multiple previous concussions and those who had sustained a concussion within the previous year had a markedly greater duration of symptoms than those with no previous concussion. Conversely, patients who had only a single previous concussion that occurred more than a year before their current injury had no statistical difference in duration of symptoms from children without a previous concussion. These findings, which suggest both temporal vulnerability and a dose-response effect of previous injuries, support previous research in animal models of concussive brain injury.

Previous studies in rodents have demonstrated cumulative effects of repetitive mild head injuries. Additionally, several of these studies suggest a temporal window of vulnerability when the repeat trauma has a more pronounced effect. One study observed that whereas mice concussed at monthly intervals performed similarly to noninjured mice on tests of learning and memory, animals concussed at weekly and daily intervals developed persistent cognitive deficits, with the daily concussion group showing ongoing effects up to 1 year after the injury compared with controls. Other animal models have offered possible biological mechanisms for this temporal vulnerability. Longhi et al showed evidence of axonal injury and cytoskeletal damage that was significantly greater in mice that received a second concussion within 3 to 5 days of an initial head injury than those who had been subjected to only a single concussion. Vagnozzi et al found a similar effect in rats and correlated it to reversible impairments in mitochondrial enzymes. Our study demonstrates this temporally sensitive effect of previous concussion for the first time in humans. This has

### TABLE 1 Characteristics of Patients With and Without Follow-up Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Included in Study, n = 235</th>
<th>Lost to Follow-up, n = 45</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
<td>14.3</td>
<td>13.6</td>
<td>.05</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>135 (57.4)</td>
<td>28 (62.2)</td>
<td>.55</td>
</tr>
<tr>
<td>Nonwhite race, n (%)</td>
<td>96 (21.3)</td>
<td>19 (42.2)</td>
<td>.063</td>
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<tr>
<td>Hispanic ethnicity, n (%)</td>
<td>20 (8.5)</td>
<td>10 (22.2)</td>
<td>.005</td>
</tr>
<tr>
<td>Sports-related concussion, n (%)</td>
<td>150 (63.8)</td>
<td>23 (51.1)</td>
<td>.11</td>
</tr>
<tr>
<td>LOC, n (%)</td>
<td>52 (22.1)</td>
<td>10 (22.2)</td>
<td>.97</td>
</tr>
<tr>
<td>Amnesia, n (%)</td>
<td>101 (43.0)</td>
<td>15 (33.3)</td>
<td>.22</td>
</tr>
<tr>
<td>Previous concussion, n (%)</td>
<td>68 (28.9)</td>
<td>11 (24.4)</td>
<td>.54</td>
</tr>
<tr>
<td>PMH migraine, n (%)</td>
<td>29 (12.3)</td>
<td>9 (20.0)</td>
<td>.17</td>
</tr>
<tr>
<td>PMH ADHD, n (%)</td>
<td>30 (12.8)</td>
<td>5 (11.1)</td>
<td>.75</td>
</tr>
<tr>
<td>PMH depression, n (%)</td>
<td>35 (14.9)</td>
<td>13 (28.9)</td>
<td>.02</td>
</tr>
<tr>
<td>PMH anxiety, n (%)</td>
<td>15 (6.4)</td>
<td>5 (11.1)</td>
<td>.34</td>
</tr>
<tr>
<td>Mean total RPSQ score</td>
<td>18.83</td>
<td>18.13</td>
<td>.75</td>
</tr>
</tbody>
</table>

LD, learning disability; PMH, previous medical history.
<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Time to Symptom Resolution Stratified by Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>All Patients</td>
<td>235</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>135</td>
</tr>
<tr>
<td>Female</td>
<td>100</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>&lt;13</td>
<td>61</td>
</tr>
<tr>
<td>≥13</td>
<td>174</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>185</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>50</td>
</tr>
<tr>
<td>Hispanic</td>
<td>20</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>208</td>
</tr>
<tr>
<td>Initial RPSQ score</td>
<td></td>
</tr>
<tr>
<td>≤18</td>
<td>121</td>
</tr>
<tr>
<td>&gt;18</td>
<td>114</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Collision</td>
<td>80</td>
</tr>
<tr>
<td>Fall</td>
<td>138</td>
</tr>
<tr>
<td>Struck by object</td>
<td>44</td>
</tr>
<tr>
<td>Motor vehicle collision</td>
<td>6</td>
</tr>
<tr>
<td>Bicycle/scooter accident</td>
<td>10</td>
</tr>
<tr>
<td>Playing sport</td>
<td>150</td>
</tr>
<tr>
<td>Injury factors</td>
<td></td>
</tr>
<tr>
<td>+LOC</td>
<td>52</td>
</tr>
<tr>
<td>−LOC</td>
<td>179</td>
</tr>
<tr>
<td>+Amnesia</td>
<td>101</td>
</tr>
<tr>
<td>−Amnesia</td>
<td>133</td>
</tr>
<tr>
<td>Previous medical history</td>
<td></td>
</tr>
<tr>
<td>Previous concussion</td>
<td>68</td>
</tr>
<tr>
<td>No previous concussion</td>
<td>167</td>
</tr>
<tr>
<td>Concussion &lt;1 y ago</td>
<td>21</td>
</tr>
<tr>
<td>Concussion &gt;1 y previous</td>
<td>47</td>
</tr>
<tr>
<td>&gt;1 previous concussion</td>
<td>19</td>
</tr>
<tr>
<td>1 previous concussion</td>
<td>49</td>
</tr>
<tr>
<td>Migraine headache</td>
<td>29</td>
</tr>
<tr>
<td>Learning disability</td>
<td>35</td>
</tr>
<tr>
<td>ADD/ADHD</td>
<td>35</td>
</tr>
<tr>
<td>Depression</td>
<td>15</td>
</tr>
<tr>
<td>Anxiety</td>
<td>21</td>
</tr>
<tr>
<td>Home medications</td>
<td></td>
</tr>
<tr>
<td>Oral contraceptive</td>
<td>11</td>
</tr>
<tr>
<td>SSRI</td>
<td>9</td>
</tr>
<tr>
<td>Stimulant</td>
<td>8</td>
</tr>
<tr>
<td>Antihistamine</td>
<td>33</td>
</tr>
<tr>
<td>Family history</td>
<td></td>
</tr>
<tr>
<td>Concussion</td>
<td>78</td>
</tr>
<tr>
<td>Migraine</td>
<td>91</td>
</tr>
<tr>
<td>Physical examination</td>
<td></td>
</tr>
<tr>
<td>GCS &lt;15</td>
<td>10</td>
</tr>
<tr>
<td>Abnormal neurologic exam</td>
<td>22</td>
</tr>
<tr>
<td>Disposition</td>
<td></td>
</tr>
<tr>
<td>Admitted</td>
<td>10</td>
</tr>
<tr>
<td>Cognitive rest advised</td>
<td>114</td>
</tr>
<tr>
<td>Physical rest advised</td>
<td>179</td>
</tr>
</tbody>
</table>

ADD, attention deficit disorder; GCS, Glasgow Coma Scale; SSRI, selective serotonin reuptake inhibitor.

* Cumulative proportion estimated with ongoing symptoms at given time by Kaplan-Meier analysis.

* Number of patients in the study minus patients censored previous to given time interval.

* Calculated as log-rank tests of significance via Kaplan-Meier analysis. Where not otherwise specified, referent group is patients without given risk factor.

* Numbers add up to less than 235 because of missing data.

* Calculated via 5-way analysis of patients with no previous concussion, previous concussion within past year, and previous concussion greater than 1 y ago.

* Calculated via 5-way analysis of patients with no previous concussion, 1 previous concussion, and more than 1 previous concussion.
direct implications on the management of athletes and other at-risk individuals who sustain concussions, supporting the concept that sufficient time to recover from a concussion may improve long-term outcomes. However, we did not find an association between physician-advised cognitive or physical rest and duration of symptoms, which

FIGURE 2
A, Kaplan-Meier curve of proportion of patients with ongoing symptoms by previous concussion history. B, Kaplan-Meier curve of proportion of patients with ongoing symptoms by timing of most recent previous concussion. C, Kaplan-Meier curve of proportion of patients with ongoing symptoms by number of previous concussions.
may reflect the limitations of our observational study. Previous studies looking at the effect of cognitive rest and abstinence from sports have been inconclusive, limited by either observational or retrospective study design. A randomized control trial will likely be necessary to address the utility of this intervention in patients.

Notably, there were several other risk factors associated with prolonged time to recovery in our study. Patients with more severe symptoms at presentation, represented by an RPSQ score >18, had more than double the median duration of symptoms compared with patients with RPSQ scores below this threshold, consistent with the findings of multiple previous studies. Additionally, our study suggests that patients 13 years and older had a longer duration of symptoms than younger children. Most previous studies examining the modifying effect of age on concussion recovery have compared high school age patients with young adults. Only Babcock et al previously compared preadolescent children to adolescents, likewise finding that younger age predicted a faster recovery. It is uncertain whether the difference between younger children and adolescents reflects differing neurobiology between the 2 groups or more severe mechanisms of injury in sports such as ice hockey and football, where games between older children involve more contact and higher-force impacts.

In our ED cohort, we demonstrate an association between LOC and shorter duration of symptoms. This is in contrast to previous studies that have shown that LOC was a risk factor for prolonged recovery or had no effect at all. Our findings may reflect a referral bias, in which patients with LOC are more likely to present to the ED on the basis of this factor alone, whereas those without LOC may be referred to the ED only when their symptoms or injury mechanism are severe. Alternatively, it is possible that patients who lose consciousness as a result of their injury may be more likely to comply with medical recommendations of physical and cognitive rest than those who did not lose consciousness, thus speeding recovery from their injury. We cannot, however, eliminate the possibility that there is a biological basis to this finding, in which mechanisms of injury responsible for LOC and those responsible for long-term neurocognitive sequelae may differ.

Some of the potential predictors of prolonged recovery that did not have a statistical association with duration of symptoms are listed in Table 3. The table shows the hazard ratios and P-values for each predictor variable.

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Hazard Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonwhite race</td>
<td>0.844</td>
<td>.40</td>
</tr>
<tr>
<td>Hispanic ethnicity</td>
<td>1.01</td>
<td>.97</td>
</tr>
<tr>
<td>Female gender</td>
<td>1.294</td>
<td>.11</td>
</tr>
<tr>
<td>Age 13 or older</td>
<td>1.404</td>
<td>.04</td>
</tr>
<tr>
<td>RPSQ &gt; 18</td>
<td>1.638</td>
<td>.002</td>
</tr>
<tr>
<td>Previous concussion</td>
<td>1.489</td>
<td>.03</td>
</tr>
<tr>
<td>Loss of consciousness</td>
<td>0.648</td>
<td>.02</td>
</tr>
<tr>
<td>History of depression</td>
<td>1.978</td>
<td>.09</td>
</tr>
</tbody>
</table>

FIGURE 2
Continued.

TABLE 3 Multivariate Cox Regression Model of Prolonged Recovery

Number of Previous Concussion
- None
- 1 previous concussion
- 2 or more previous concussions
+ Censored

Proportion Symptomatic

Days

0

1.0

0.8

0.6

0.4

0.2

0.0

0

20

40

60

80

100
symptoms in our study are also noteworthy. In the multivariate analysis, female gender did not predict prolonged recovery, although there appeared to be a difference between the genders in univariate analysis. This is nearly identical to the results of Babcock et al, and likely because female patients had more severe symptoms at presentation in our study (mean initial RPSQ 21.3 vs 17.0 in male patients, P = .02), thus representing a confounding variable. Whether this finding is indicative of the fact that female patients have more severe symptoms from concussion in general, as suggested in several previous studies, or is due to referral bias in which female individuals preferentially present to the ED when symptoms are more severe than male counterparts cannot be ascertained from our data.

We also observed that patients with a history of migraine headaches, depression, ADHD, and anxiety did not have prolonged symptoms after concussion; however, small sample size limits our ability to detect relationships in these specific patient populations.

Patients in our study had a longer duration of symptoms than most previous reports in the literature, which have frequently shown symptoms resolving by 7 to 10 days after the injury. This may be because of differences in study populations, as children presenting to an ED may represent a more severe subset of concussed patients than the outpatient cohorts previously studied. The RPSQ may also be more sensitive to ongoing symptoms than the self-assessment tools or neurocognitive testing used in many other studies.

There are several limitations to our study. Although we enrolled 93% of patients approached to participate, there were additional patients who were not contacted by the research coordinators. The most common reason for this were arrival to the ED during a time when no research coordinator was available and short length of ED stay, leading to discharge before the patient could be contacted about enrollment. Second, by using survival analysis to best account for censored data, we assumed that there was no difference between patients who were censored and those who were not. Although this assumption appears to be valid based on similar demographics and symptom scores of censored versus uncensored patients, it is possible that patients ultimately failed to complete the study because of more bothersome symptoms or, conversely, more rapid symptom resolution. A final limitation is the accuracy of self-reported symptoms: certain subgroups of the population, notably athletes, may have had an incentive to report symptom resolution to expedite return-to-play; others may report symptoms that are no longer present to avoid schoolwork; still others may have a difficult time understanding the questions of the RPSQ.

Despite these limitations, our study had several strengths, including a large sample size and prospective methodology. We enrolled a high percentage of eligible patients and most patients continued participation until symptom resolution. By serially surveying patients at short time intervals and asking for the specific date of symptom resolution within that interval, our estimates of symptom duration are likely to be more accurate than if we used a single follow-up questionnaire months after the injury.

Finally, unlike previous studies that focused on particular subgroups of patients, such as participants in a particular sport, our study examined all eligible patients who presented to a tertiary care ED. As a result, we studied a diverse group in terms of both demographics and mechanisms of injury, potentially making our study more generalizable to medical providers practicing in the primary care and ED settings than samples of selected populations.

CONCLUSION

Children with a history of a previous concussion, particularly those with recent or multiple concussions, are at increased risk for prolonged symptoms after concussion. These findings have direct implications on the management of concussion patients, particularly those at high risk for future concusive injuries, such as athletes.

ACKNOWLEDGMENTS

Michael Monuteau, ScD, provided statistical guidance and support. Rich Bachur, MD, and Mark Neuman, MD, provided mentorship and manuscript review. Chris Landrigan, MD, assisted with manuscript review. Mark Berry, MA, provided programming and administrative support. The research coordinator team (Elizabeth Paulsen, BS, Lucy Abernethy, BA, Kaitlin Morris, BA, Hillary Chu, BA, and Jessica LeSage, BS) enrolled and followed up with patients and provided administrative support.

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REMOTE MONITORING: At our University, all students taking an examination must be monitored by a proctor who is physically present in the room in which the examination is being given. Although somewhat cumbersome, the system works when all students take the exam together in one place. However, the policy begins to break down when several students need to take exams at different times, or have accommodations allowing extra time to complete the exam. Suddenly, we do not have enough proctors. The situation is even more complex when one considers massive open online courses (MOOC) which can have enrollments of 40,000 or more students. Historically not for credit, more MOOC courses are offering examinations and course credits, and monitoring students for cheating while taking a test in an MOOC is challenging. Requiring students to take examinations in a regional testing center is often unrealistic and too costly for most. However, a few companies now offer electronic surveillance of MOOC test-takers (using the kind of gadgetry one might expect someone like James Bond, not an online course, to need). This surveillance is just as good as, if not better than, using live proctors in traditional courses. As reported in The New York Times (Technology: March 3, 2013), test-taker identity can be confirmed remotely by checking photo IDs and signatures – and, in a new twist, by comparing typing styles (e.g., how long individual keys are depressed while typing a specified phrase) to those on record. Techniques to detect cheating include video monitoring, keystroke surveillance, screen sharing, and the use of sophisticated computer algorithms. Students can be monitored in real time, or sessions can be recorded and then replayed later (at high speed) in order to detect any aberrations. The costs to monitor the examination are often borne by the student, and range from around $15 to $100 (depending on the class and type of monitoring). A number of universities already make use of the programs offered by these companies, and report high satisfaction. While many of these techniques have been designed for MOOC, there is no reason they cannot be applied to examinations given in traditional classes at “brick and mortar” universities. While some complain that a webcam is intrusive, so is an exam monitor. I personally hope we can move away from sit-down exams at a specified time with a proctor, and move to a more open system where students take the exam when ready, where ready, using the same proctor-free technology being used in MOOCs.

Noted by WVR, MD