Duration and Course of Post-Concussive Symptoms

AUTHORS: Matthew A. Eisenberg, MD, William P. Meehan III, 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, post-concussion syndrome, traumatic brain injury

ABBREVIATIONS
ED—emergency department
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 manuscript preparation; Dr Mannix was responsible for study conception, study design, data analysis, and manuscript preparation; Dr Meehan was responsible for study conception, study design, and manuscript preparation; and all authors approved the final manuscript as submitted.

www.pediatrics.org/cgi/doi/10.1542/peds.2014-0158

doi:10.1542/peds.2014-0158

Accepted for publication Feb 26, 2014

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).

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.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

WHAT'S KNOWN ON THIS SUBJECT: Although there has been increasing research into the effects of concussion on the developing brain in recent years, little is known about the expected duration and clinical course of individual post-concussive symptoms in children.

WHAT THIS STUDY ADDS: Children and adolescents have a significant burden of disease after concussion, with typical patients experiencing physical effects such as headache immediately after the injury, emotional symptoms later in the recovery period, and cognitive symptoms that may be present throughout.

abstract

FREE

OBJECTIVES: To examine the incidence, duration, and clinical course of individual post-concussive symptoms in patients presenting to a pediatric emergency department (ED) with a concussion.

METHODS: We conducted secondary analysis of a prospective cohort study of patients 11 to 22 years old presenting to the ED of a children's hospital with an acute concussion. The main outcome measure was duration of symptoms, assessed by the Rivermead Post-Concussion Symptoms Questionnaire (RPSQ). Patients initially completed a questionnaire describing mechanism of injury, associated symptoms, past medical history, and the RPSQ, then were serially administered the RPSQ for 3 months after the concussion or until all symptoms resolved.

RESULTS: Headache, fatigue, dizziness, and taking longer to think were the most common symptoms encountered at presentation, whereas sleep disturbance, frustration, forgetfulness, and fatigue were the symptoms most likely to develop during the follow-up period that had not initially been present. Median duration of symptoms was the longest for irritability (16 days), sleep disturbance (16 days), frustration (14 days), and poor concentration (14 days), whereas nausea, depression, dizziness, and double-vision abated most quickly. One month after injury, nearly a quarter of children still complained of headache, >20% suffered from fatigue, and nearly 20% reported taking longer to think.

CONCLUSIONS: Among patients presenting to a pediatric ED after a concussion, physical symptoms such as headache predominate immediately after the injury, emotional symptoms tend to develop later in the recovery period, and cognitive symptoms may be present throughout. *Pediatrics* 2014;133:999–1006

Mild traumatic brain injury (mTBI) remains one of the most common reasons children present for medical care in the United States,[1–3] and concerns about its effects on the developing brain have led to a large number of recent studies examining pediatric concussion. Despite this, the expected course of individual post-concussive symptoms in children has not been well described. There is thus little evidence to help guide physicians, patients, and their families regarding incidence and duration of such typical complaints after a head injury as fatigue, poor concentration, and irritability.

Estimates as to duration of post-concussive symptoms in children range widely, with reports showing as few as 10% of patients symptomatic 7 days after sport-related concussion[4] to as many as 43% still with symptoms 3 months after being hospitalized for mTBI.[5] One cohort study conducted in the emergency department (ED) setting showed 29.3% of children aged 5 to 18 years still symptomatic 3 months after sustaining a concussion, with the most common symptoms being headache, fatigue, and frustration.[6] Another study of children 18 years and younger demonstrated that 11% of patients who had a concussion were symptomatic at the 3-month mark, with fatigue, emotional lability, and irritability being the most common enduring symptoms.[7] In a smaller group of adolescents hospitalized for mTBI, sleep issues, difficulty concentrating, and feeling "slower" were the most common symptoms reported at a 2- to 3-week follow-up visit.[5]

To our knowledge, only 1 study has attempted to delineate the course of specific post-concussive symptoms in children. This prospective cohort study of patients aged 5 to 17 years who had mTBI focused exclusively on headaches, finding the prevalence of this symptom was 43% 3 months after injury and 41% a full 12 months later.[8] For concussed children, their families, and their physicians, an understanding of the time course over which specific symptoms resolve after a head injury is important to optimally manage and set expectations for recovery. In a previous study of children and adolescents presenting to a pediatric ED after an acute concussion, we sought to identify demographic and injury factors that would predict a prolonged recovery period. Our previous results showed that the median time to resolution from all post-concussive symptoms was 13 days, with >30% of patients still symptomatic 4 weeks after injury.[9] In this study, we performed a secondary analysis of this same cohort, to examine individual post-concussive symptoms and better define their incidence, duration, and clinical course.

METHODS

Study Design and Population

We conducted secondary analysis of 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 or to the body with impulsive force transmitted to the head that resulted in either (1) alteration of mental status, or (2) any of the following symptoms that started after the injury and were not present before the injury: headache, nausea, vomiting, dizziness/balance problems, fatigue, drowsiness, blurred vision, memory difficulty, or difficulty concentrating, without evidence of intracranial hemorrhage. We chose this broad definition to include both those who had alteration of consciousness and those who presented with typical post-concussive symptoms following a head injury.[10–12]

Patients were excluded from the study if any of the following were present: (1) Glasgow Coma Score (GCS) <13 on arrival to the ED, (2) coexisting fracture of skull or long-bone, (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 post-concussive symptoms from symptoms related to other injuries or psychological stresses related to major trauma or assault.

Outcomes

The primary outcome was time course of recovery of individual post-concussive symptoms assessed via the Rivermead Post-Concussion Symptoms Questionnaire (RPSQ). The RPSQ is a 16-item concussion symptom inventory checklist that has been used extensively in both adult and pediatric studies of mTBI,[7,13,14] has shown a high degree of inter-rater and test-retest reliability,[15,16] and is valid and unbiased in young children.[14,17] The questionnaire was available to study participants in both English and Spanish. Symptom duration was defined as the amount of time between the date that the patient first reported the symptom present at greater than pre-injury baseline (score of 2 or higher on the symptom inventory) and the date that the patient first reported that the symptom was no longer present or was back to pre-injury level (score of 0 or 1 on the symptom inventory). On follow-up questionnaires, patients additionally were asked to report their amount of cognitive and athletic activity on a 5-point scale ranging from full rest to full participation, and to compare current school and athletic performance to their pre-injury performance.

Enrollment and Consent

Study participants were enrolled during their ED visit by trained research coordinators after informed consent (and assent for patients age <18 years) was obtained. Eligible patients who were not contacted during their ED visit were offered enrollment after ED discharge via phone if they were still within 72 hours of the injury. On enrollment, patients completed an electronic questionnaire asking for demographic information, mechanism of injury, associated symptoms, past medical history, and the RPSQ. Data regarding patient medical history was culled from this self-report and a questionnaire filled out by the ED provider, with selective chart review performed to clarify discrepancies.

Follow-Up

An online follow-up questionnaire containing the RPSQ was sent electronically to patients or their parent, depending on family preference, 1, 2, 4, 6, 8, and 12 weeks after their ED visit or until they met criteria for symptom resolution, defined as all indices of the RPSQ scored a 0 or 1. Study participation terminated with the week-12 questionnaire. Instructions requested that the patient fill out the survey with the assistance of the parents as needed. Patients who reported resolution of symptoms were prompted to provide the last date on which any symptoms occurred. Patients who had incomplete or inconsistent data were called to resolve these issues. Patients who failed over 2 consecutive intervals to fill out the questionnaire were considered lost to follow-up. Study data were collected and managed by using REDCap (Research Electronic Data Capture, Nashville, TN) electronic data capture tools hosted at Boston Children's Hospital.[18]

Statistical Analysis

Statistical analysis was performed by using PASW Statistics 18 (SPSS, Inc, Chicago, IL). Continuous data were analyzed by Student's *t* test or Wilcoxon Rank Sum test as appropriate. Median symptom duration was assessed as a continuous variable from 0 to 90 days using Kaplan-Meier analysis, a measure that takes into account expected duration of symptoms for censored patients (those who were either lost to follow-up or still symptomatic at the end of the study period). Percent of patients symptomatic at each time point was calculated by dividing the number of patients reporting the symptom at the specified time by the number of patients who either met criteria for symptom resolution or were still actively being followed at that time point. Values were considered statistically significant if $P \leq .05$. The Boston Children's Hospital Institutional Review Board approved this study before onset of data collection.

RESULTS

Study Population

Of 302 patients approached for the study, 280 (93%) were enrolled; 235 (84%) of these patients completed at least 1 follow-up questionnaire, and 45 (16%) were lost to follow-up. Sixty-six percent were enrolled on the calendar day their concussion occurred, 24.7% the next calendar day, 7.2% 2 days later, and 1.7% 3 days later. Demographics and characteristics of patients who were included in the study and those who were lost to follow-up are shown in Table 1.

Course of Symptoms

Although headache, fatigue, dizziness, and taking longer to think were the most common symptoms encountered at presentation, sleep disturbance, frustration, forgetfulness, and fatigue were the symptoms most likely to develop during the follow-up period that had not been present initially after the injury (Table 2).

Duration of Symptoms

Irritability, sleep disturbance, frustration, and poor concentration persisted the longest, whereas nausea, depression, dizziness, and double vision abated the most quickly (Table 2). One month after injury, nearly one-quarter of children still complained of headache, >20% suffered from fatigue, and nearly 20% reported taking longer to think (Figs 1 and 2).

Cognitive Rest, School, and Athletic Performance

One week after the injury, 197 subjects completed the questionnaire regarding cognitive and sports activity and school and athletic performance. Fifty-seven percent of patients reported at least moderately limiting cognitive activity, whereas 15.2% limited cognitive activity only minimally and 27.4% had not limited cognitive activity at all. Eighteen percent of patients reported worse school performance than before their concussion, whereas 48.2% reported no decline in school work (the remainder had not attended school or done any school work in the interim). Only 8.2% of patients had returned to full athletic activity, with the majority (63.8%) reporting no athletic activity at all except for walking.

DISCUSSION

To our knowledge, this is the first report to describe the precise duration of individual symptoms after pediatric concussion. Previous studies have demonstrated that post-concussive symptoms can be broadly categorized into physical, emotional, and cognitive clusters, with a high degree of overlap between them,[19–22] but neither the incidence of these symptoms nor their relative burden throughout the recovery period have been well described in children.[23,24] Here we show that although the majority of children initially present to care after

TABLE 1 Patient Demographics

	Included in Study ($N = 235$)	Lost to Follow-up ($N = 45$)	P Value
Mean age (y)	14.3	13.6	.05
Male gender	57.4	62.2	.55
Non-white race	21.3	42.2	.003
Hispanic ethnicity	8.5	22.2	.005
LOC	22.1	22.2	.97
Amnesia	43.0	33.3	.22
Previous concussion	28.9	24.4	.54
PMH migraine	12.3	20.0	.17
PMH LD	12.8	11.1	.75
PMH ADHD	14.9	28.9	.02
PMH depression	6.4	11.1	.34
PMH anxiety	8.9	11.1	.58
Mean total RPSQ score	18.83	18.13	.75
Mechanism of injury			
Collision	34.0	22.2	.12
Fall	41.3	37.8	.60
Struck by object	18.7	33.3	.03
Motor vehicle collision	2.6	4.4	.49
Bicycle/scooter accident	4.3	4.4	.95
Playing sport	63.8	51.1	.11
Imaging performed			
CT	23.4	13.2	.25
MRI	0.5	0	.84
GCS			.59
GCS 15	95.2	100	
GCS 14	3.4	0	
GCS 13	1.4	0	
Admitted	4.8	2.6	.55

All data are presented as percentages unless otherwise noted. ADHD, attention-deficit/hyperactivity disorder; CT, computed tomography; GCS, Glasgow Coma Scale; LD, learning disability; LOC, loss of consciousness; PMH, previous medical history.

a concussion with symptoms of headache, dizziness, and fatigue, new symptoms often develop during the recovery course, particularly those that have a substantial emotional component. Whether this secondary symptom development is attributable to the underlying pathophysiology of mTBI or the psychosocial consequences of the concussion and the restrictions placed on children during their recovery is not known. Understanding the recovery course for children after concussion is important for caregivers and families who will be managing symptoms, as well as for academic and athletic accommodations.

For the majority of patients in our study, symptoms resolved within 2 weeks of the injury. During that recovery period, however, patients experienced a large symptom burden and significant impact on subjective functioning. One week after the injury, more than two-thirds of the patients still had a headache; a majority complained of poor concentration, dizziness, fatigue, and taking longer to think; and >40% struggled with forgetfulness, light sensitivity, and noise sensitivity. Few patients had returned to full cognitive activity or sports participation 1 week after the injury, although we cannot say whether these limitations were attributable to symptoms or to clinician advice to rest. Taken together, these findings show that although concussion symptoms often resolve quickly, they can be debilitating in the short term for many patients.

Our study adds to previous investigations that have demonstrated that headache is the most commonly reported post-concussive symptom,[5,6,8,25–28] present in 85.1% of children in our cohort on presentation to the ED and in 88.9% of patients at any point during the follow-up period. We found that the median duration of headache was 13 days, with 5.3% still having headache at 3 months, notably less than the 43% reported by Blume and colleagues in a previous pediatric mTBI cohort.[8] We believe differing survey methodology explains these discrepant findings, as participants in Dr Blume's study were asked to rate their pain on a scale of 0 to 10, with any score ≥1 considered positive for presence of headache. In our study, on the other hand, we considered a patient to have ongoing headache only if they indicated that their pain was greater than their pre-injury baseline on the RPSQ.

After headache, fatigue was the second most common presenting symptom in our study, reported by 64.2% of patients on initial evaluation. Notably, an additional 15.4% of children who did not initially report fatigue subsequently developed this symptom. A substantial number of children (21.6%) also developed sleep disturbance after their initial evaluation. This finding suggests that children who have a concussion should be warned about the possibility of developing fatigue and sleep issues, and these symptoms should be specifically assessed during follow-up evaluation. Moreover, despite being characterized as somatic symptoms, both sleep issues and fatigue may have a significant emotional component, so careful attention should be paid to coincident emotional symptoms in children who have these complaints.[21]

The emotional symptoms of concussion (frustration, depression, irritability, and restlessness) were not commonly reported on presentation, but did develop in large numbers of patients during follow-up and were among the symptoms that lasted the longest. An exception to this was depression, which developed in only 8.6% of patients who did not report it initially. It is unclear whether this reflects the fact that depression itself did not develop as

TABLE 2 Time to Resolution of Individual Post-Concussive Symptoms

	% Reporting Symptom at Presentation	% Developing Symptom After Initial Assessment	% With Symptoms on Day 7 ($N = 234$)[a]	% With Symptoms on Day 28 ($N = 218$)[a]	% With Symptoms on Day 90 ($N = 207$)[a]	Median Days of Symptom (95% CI)
All symptoms	n/a	n/a	77	32	15	13 (11–15)
Physical symptoms						
Blurry vision	32	5.4	31.6	6	1.4	11 (9–13)
Dizziness	61.3	6.8	53	14.2	3.9	10 (8–12)
Double vision	13.2	2.1	12.8	1.8	0.5	10 (9–11)
Fatigue	64.2	15.4	59.8	21.6	3.4	13 (11–15)
Headache	85.1	3.8	69.2	24.8	5.2	12 (10–14)
Light sensitivity	42.5	10.7	44	13.8	1.9	13 (10–16)
Nausea	41.6	3.9	37.2	8.7	2.4	9 (8–10)
Noise sensitivity	40.4	14	43.2	12.4	1.9	11 (10–12)
Sleep disturbance	11.6	21.6	24.8	10.1	1	16 (10–22)
Cognitive symptoms						
Forgetfulness	42.1	15.8	44	14.	1.9	11 (8–14)
Poor concentration	52.4	13.1	56.8	17	3.4	14 (12–16)
Taking longer to think	57.8	11.1	54.3	18.3	4.3	13 (10–16)
Emotional symptoms						
Depression	22.9	8.6	25.6	8.3	1.4	9 (7–11)
Frustration	27.7	17.4	37.6	14.7	1.4	14 (8–20)
Irritability	25.5	14.5	30.3	14.2	1.9	16 (9–23)
Restlessness	24.6	14.1	31.6	10.6	1.4	12 (9–15)

CI, 95% confidence interval; n/a, not applicable.

[a] Number of patients in the study minus patients censored before given time interval.

frequently as other complaints, or that patients were reticent to endorse depression owing to the stigma associated with this symptom. Pediatricians and specialists in concussion care should continue to carefully evaluate patients for the emotional symptoms of concussions attributable to both the physical injury and the psychosocial sequelae that often follow these head injuries.

Cognitive symptoms were particularly burdensome in our cohort, as they were present in substantial percentages initially, still went on to develop in many additional patients, and had greater than average duration of symptoms, with the exception of forgetfulness, which resolved on average within 11 days. These findings support the importance of academic accommodations for children after concussion.

Allowing for overlap between domains and some notable exceptions outlined above, our study shows that the physical symptoms of concussion present early and resolve early after the injury, emotional symptoms develop later than the other domains, and cognitive symptoms impair many patients both immediately after their head trauma and long into the recovery period. Understanding this expected progression of symptoms has several potential benefits. For patients, it may help to normalize the experience of recovery from concussion, preventing the additional stress that comes from worrying that symptoms are unusual or excessive. For families and school personnel, this knowledge may help them better prepare the home and school environment for expected obstacles to recovery and return to normal academic and athletic participation. For health care providers, it may help reduce unnecessary testing and referrals owing to concern that a patient's course is atypical, better target post-concussive evaluations to expected symptoms, and better inform the anticipatory guidance given to patients and their families.

There are several limitations to our study. We did not include a control group, so we cannot conclude with certainty that the symptoms experienced by patients in our cohort are attributable to the head injury and not part of the recovery from injury in general, the psychosocial consequences of illness, or malingering. A wide body of literature, however, has established that post-concussive symptoms are more frequent in mTBI patients than in other injured patients, and that post-concussion syndrome should be recognized as a unique and valid diagnosis apart from other forms of recovery from trauma.[7,29–31]

An additional limitation is that we studied only self-reported symptoms, and patient reports may have been influenced by a desire to either expedite or, conversely, avoid return to school or sports. Furthermore, although we surveyed patients frequently during the study period, our primary focus was on pinpointing the date on which all symptoms resolved, not individual symptoms. As a result, we defined the duration of a symptom as the time from which a patient first reported the symptom until the time that the patient first reported that the symptom was no longer present. This number may have been shorter or

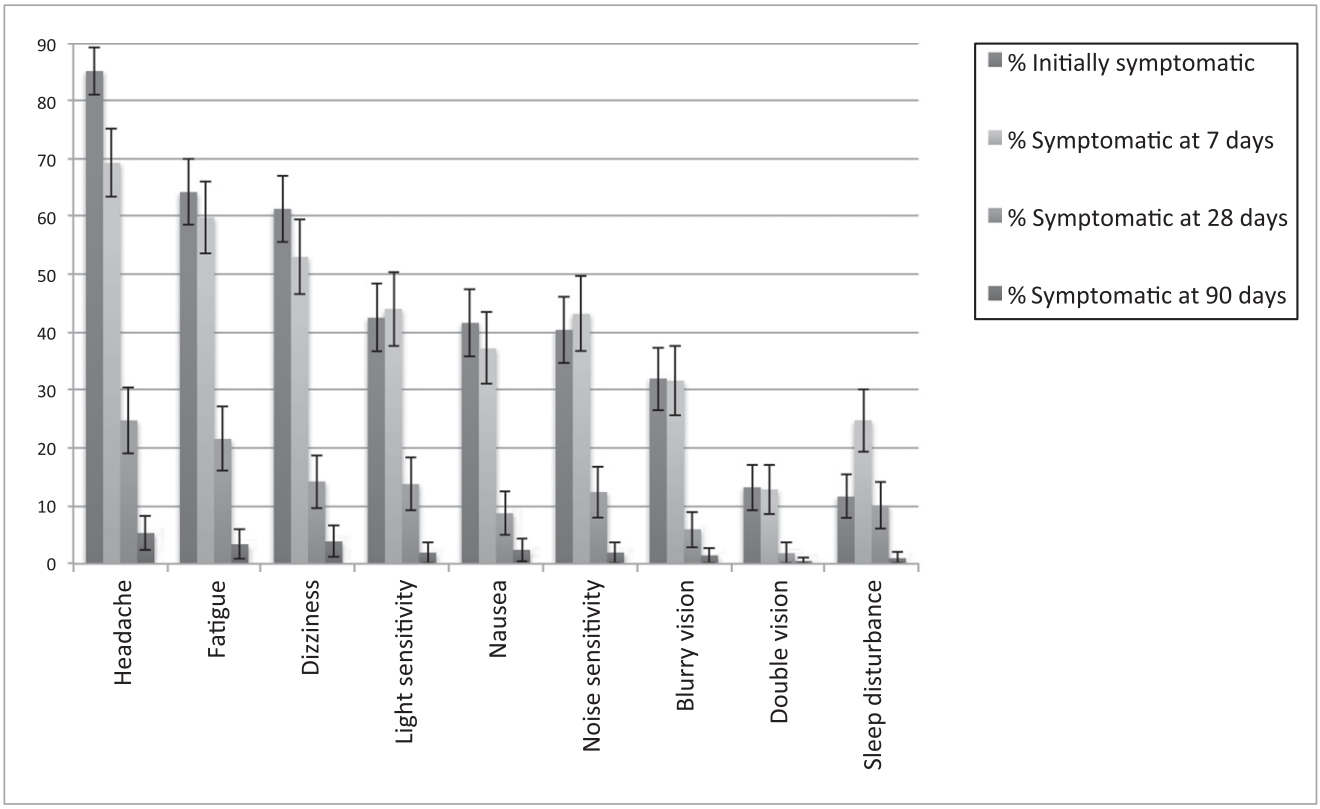

FIGURE 1
Percent of patients reporting individual physical symptoms during study period. Bars represent 95% CI.

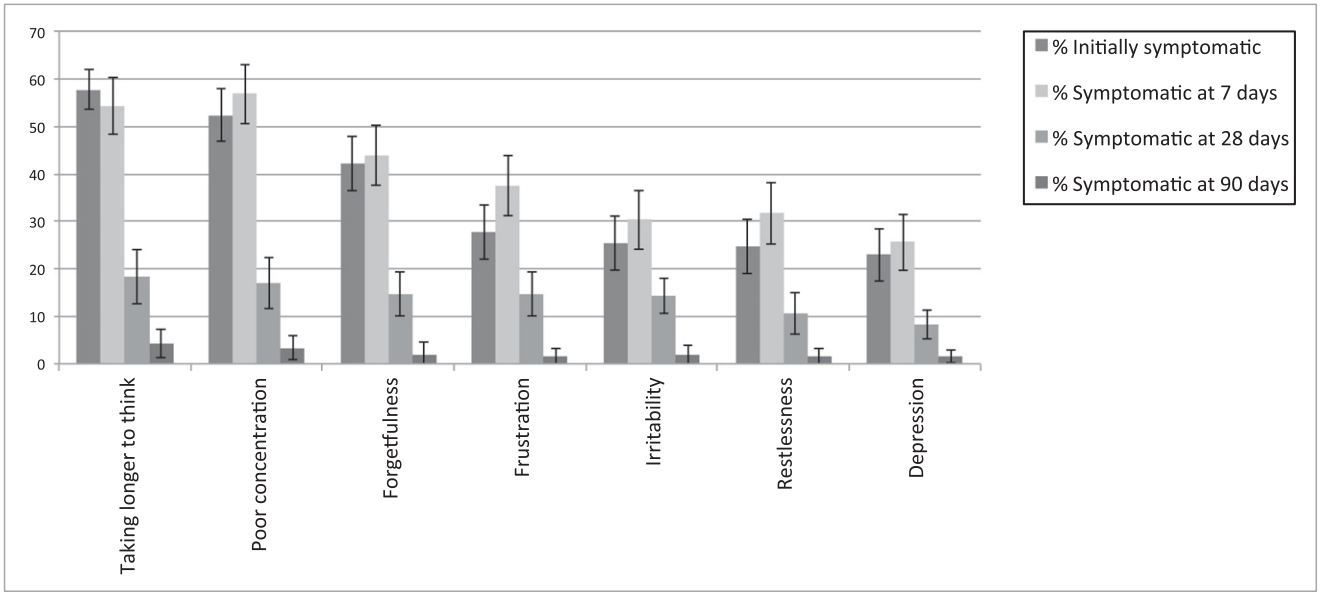

FIGURE 2
Percent of patients reporting individual cognitive and emotional symptoms during study period. Bars represent 95% CI.

longer than the actual symptom duration, depending on the timing of the questionnaire being filled out. However, because we surveyed patients frequently during the follow-up period, we believe these estimates are likely to more closely approximate symptom duration than a single follow-up questionnaire administered at 1

given time point after the injury. Another limitation may come from the small number of patients who were enrolled after their ED visit, and whose initial questionnaire may therefore reflect the symptoms present in the hours to days after the initial injury, rather than those present at the time of their ED evaluation. Given the small number of patients in this category and the short time window in which they were required to fill out the questionnaire after the head injury, we think this effect is likely to be small.

There were differences between our study population and the group that was lost to follow-up in terms of race, ethnicity, and presence of attention-deficit/hyperactivity disorder, although there were no differences in other factors that have been shown to influence concussion outcome, such as age, gender, loss of consciousness, previous concussion, or initial symptom burden. Finally, our study population consisted of children and adolescents referred to a tertiary care pediatric ED. This group likely represents a more severely injured subset of concussion patients than those who are treated on the field, in an outpatient clinic, or in a community ED, as patients may be treated initially in these latter settings and then be referred to a pediatric ED owing to severity of symptoms or need for imaging, subspecialty consultation, or admission. As a result, these results may not be generalizable to all children and adolescents after a concussion.

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 a majority of patients continued participation until symptom resolution. 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.

CONCLUSIONS

Among children and adolescents presenting to a pediatric ED after a concussion, there is a significant burden of disease, particularly during the first 2 weeks after injury. The typical patient will see physical effects such as headache immediately after the injury, emotional symptoms that develop later in the recovery period, and cognitive symptoms may be present throughout.

ACKNOWLEDGMENTS

Michael Monutaeux, ScD, provided statistical guidance and support. Mark Berry, MA, provided programming and administrative support. Mark Neuman, MD, and Lise Nigrovic, MD, assisted with manuscript review. The research coordinator team (John Andrea, BS, 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.

REFERENCES

1. Guerriero RM, Proctor MR, Mannix R, Meehan WP III. Epidemiology, trends, assessment and management of sport-related concussion in United States high schools. *Curr Opin Pediatr*. 2012;24(6):696–701
2. Meehan WP III, d'Hemecourt P, Comstock RD. High school concussions in the 2008-2009 academic year: mechanism, symptoms, and management. *Am J Sports Med*. 2010;38(12):2405–2409
3. Meehan WP III, Mannix R. Pediatric concussions in United States emergency departments in the years 2002 to 2006. *J Pediatr*. 2010;157(6):889–893
4. McCrea M, Guskiewicz K, Randolph C, et al. Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *J Int Neuropsychol Soc*. 2013;19(1):22–33
5. Blinman TA, Houseknecht E, Snyder C, Wiebe DJ, Nance ML. Postconcussive symptoms in hospitalized pediatric patients after mild traumatic brain injury. *J Pediatr Surg*. 2009;44(6):1223–1228
6. Babcock L, Byczkowski T, Wade SL, Ho M, Mookerjee S, Bazarian JJ. Predicting postconcussion syndrome after mild traumatic brain injury in children and adolescents who present to the emergency department. *Arch Pediatr Adolesc Med*. 2012;167(2):156–161
7. Barlow KM, Crawford S, Stevenson A, Sandhu SS, Belanger F, Dewey D. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics*. 2010;126(2). Available at: www.pediatrics.org/cgi/content/full/126/2/e374
8. Blume HK, Vavilala MS, Jaffe KM, et al. Headache after pediatric traumatic brain injury: a cohort study. *Pediatrics*. 2012;129(1). Available at: www.pediatrics.org/cgi/content/full/129/1/e31
9. Eisenberg MA, Andrea J, Meehan W, Mannix R. Time interval between concussions and symptom duration. *Pediatrics*. 2013;132(1):8–17
10. Halstead ME, Walter KD; Council on Sports Medicine and Fitness. American Academy of Pediatrics. Clinical report—sport-related concussion in children and adolescents. *Pediatrics*. 2010;126(3):597–615
11. Ropper AH, Gorson KC. Clinical practice. Concussion. *N Engl J Med*. 2007;356(2):166–172
12. Meehan WP III, Bachur RG. Sport-related concussion. *Pediatrics*. 2009;123(1):114–123
13. Faux S, Sheedy J, Delaney R, Riopelle R. Emergency department prediction of postconcussive syndrome following mild traumatic brain injury—an international cross-validation study. *Brain Inj*. 2011;25:14–22
14. Gagnon I, Swaine B, Friedman D, Forget R. Exploring children's self-efficacy related to physical activity performance after a mild traumatic brain injury. *J Head Trauma Rehabil*. 2005;20(5):436–449
15. King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. *J Neurol*. 1995;242(9):587–592
16. Eyres S, Carey A, Gilworth G, Neumann V, Tennant A. Construct validity and reliability of the Rivermead Post-Concussion

Symptoms Questionnaire. *Clin Rehabil*. 2005;19(8):878–887

17. Lannsjo M, Borg J, Bjorklund G, Af Geijerstam JL, Lundgren-Nilsson A. Internal construct validity of the Rivermead Post-Concussion Symptoms Questionnaire. *J Rehab Med*. 2011;43:997–1002
18. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377–381
19. Blume H, Hawash K. Subacute concussion-related symptoms and postconcussion syndrome in pediatrics. *Curr Opin Pediatr*. 2012;24(6):724–730
20. Blume HK, Lucas S, Bell KR. Subacute concussion-related symptoms in youth. *Phys Med Rehabil Clin N Am*. 2011;22(4):665–681, viii–ix [viii-ix.]
21. Potter S, Leigh E, Wade D, Fleminger S. The Rivermead Post Concussion Symptoms Questionnaire: a confirmatory factor analysis. *J Neurol*. 2006;253(12):1603–1614
22. Piland SG, Motl RW, Guskiewicz KM, McCrea M, Ferrara MS. Structural validity of a self-report concussion-related symptom scale. *Med Sci Sports Exerc*. 2006;38(1):27–32
23. Lee LK. Controversies in the sequelae of pediatric mild traumatic brain injury. *Pediatr Emerg Care*. 2007;23(8):580–583, quiz 584–586
24. Ayr LK, Yeates KO, Taylor HG, Browne M. Dimensions of postconcussive symptoms in children with mild traumatic brain injuries. *J Int Neuropsychol Soc*. 2009;15(1):19–30
25. Casey R, Ludwig S, McCormick MC. Morbidity following minor head trauma in children. *Pediatrics*. 1986;78(3):497–502
26. Collins MW, Field M, Lovell MR, et al. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. *Am J Sports Med*. 2003;31(2):168–173
27. Mihalik JP, Stump JE, Collins MW, Lovell MR, Field M, Maroon JC. Posttraumatic migraine characteristics in athletes following sports-related concussion. *J Neurosurg*. 2005;102(5):850–855
28. Register-Mihalik J, Guskiewicz KM, Mann JD, Shields EW. The effects of headache on clinical measures of neurocognitive function. *Clin J Sport Med*. 2007;17:282–288
29. Grubenhoff JA, Kirkwood MW, Deakyne S, Wathen J. Detailed concussion symptom analysis in a paediatric ED population. *Brain Inj*. 2011;25:943–949
30. Yeates KO, Taylor HG, Rusin J, et al. Longitudinal trajectories of postconcussive symptoms in children with mild traumatic brain injuries and their relationship to acute clinical status. *Pediatrics*. 2009;123(3):735–743
31. McCauley SR, Wilde EA, Barnes A, et al. Patterns of early emotional and neuropsychological sequelae following mild traumatic brain injury. *J Neurotrauma*. 2013

LIGHT FOR CLEAN WATER: *Here in Vermont we rarely have significant drought conditions. That, unfortunately, has not been the case in the western United States. Several areas have experienced severe drought conditions for many years. Water scarcity is a huge issue for ranchers, farmers, and city dwellers alike. As reported in* The New York Times *(Technology: February 16, 2014), at least one company has developed an innovative solution that could eventually help alleviate water problems for some farmers in California's Central Valley. Instead of using solar panels to generate electricity, engineers use standard, easily acquired technology to generate heat to desalinate contaminated ground water. The Central Valley relies on irrigation to supply water for crops. There is ground water in the area, but it is so heavily tainted with toxic levels of salt and heavy metals that it cannot be used for crop irrigation and must be drained away from the fields.*

Rather than using costly mirrors to focus the sun, one approach has been to use a reflective film to heat oil suspended in long tubes over the reflective coating. The heated oil goes through evaporators to generate steam. As the steam condenses, fresh water, salts, and heavy metals are separated. The process can be repeated several times. The method has great promise as the Central Valley has plenty of both unplanted land and sunshine, and the technology is for the most part nonproprietary. While still an expensive way to generate clean water, at least farmers would have access to water, and the costs are still far less than conventional desalinization. So, in the future, there may be desalinization farms in addition to solar and windmill farms in California all trying to harness clean energy.

Noted by WVR, MD