Characteristics of Prolonged Concussion Recovery in a Pediatric Subspecialty Referral Population

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Objective To identify pre-existing characteristics associated with prolonged recovery from concussion in a sample of patients referred to a pediatric sports medicine clinic.

Study design This was a retrospective, exploratory cohort study of 247 patients age 5-18 years with concussion referred to a tertiary pediatric hospital-affiliated sports medicine clinic from July 1, 2010, through December 31, 2011. A random sample of all eligible patient visits (3740) was chosen for further review and abstraction. Statistical comparisons between subsets of patients were conducted using exact χ^2 tests, logistic regression, quantile regression, and Kaplan-Meier survival curves.

Results The median time until returning to school part-time was 12 days (IQR 6-21); until returning to school full-time without accommodations was 35 days (IQR 11-105); until becoming symptom-free was 64 days (IQR 18-119); and until being fully cleared to return to sports was 75 days (IQR 30-153). Furthermore, 73% of all patients were symptomatic for >4 weeks, 73% were prescribed some form of school accommodation, and 61% reported a decline in grades. Characteristics associated with a prolonged recovery included a history of depression or anxiety; an initial complaint of dizziness; abnormal convergence or symptom provocation following oculomotor examination on physical examination; and history of prior concussion.

Conclusions Pediatric and adolescent patients with concussion may experience cognitive and emotional morbidity that can last for several months following injury. Clinicians should consider specific pre-existing characteristics and presenting symptoms that may be associated with a more complicated recovery for concussion patients. *(J Pediatr 2014;165:1207-15)*.

Sports- and recreation-related concussions are common childhood injuries. Prior studies have estimated that nearly 150 000 children and adolescents are seen in emergency departments for concussion each year.[1] Including adults, the total number of sports-related traumatic brain injuries has been estimated to be between 1.8 and 3.8 million annually.[2-5] Because of both increasing awareness and diagnosis, as well as increasing incidence of injury, the rate of concussion among children continues to rise and has been estimated to have doubled in the past 15 years.[6]

Pediatric and adolescent patients with concussion are at risk for significant cognitive[7,8] and emotional morbidity, including emotional lability, irritability, and depression.[5,9] Recent studies have begun to delineate factors predisposing youth athletes to a more prolonged recovery, including a history of 3 or more prior concussions[10-12] and adolescent age.[13,14] Certain presenting symptoms, including dizziness, headache, and migrainous-like symptoms (post-traumatic migraine) have also been associated with prolonged recovery in youth athletes.[12,15-17] Adult data have shown those with pre-existing depression have more severe acute neurocognitive deficits than those without depression.[18,19] Less is known, however, about pre-existing patient characteristics that predispose children and adolescents to prolonged recovery from concussions.

By examining a sample of patients referred to a specialty pediatric sports medicine clinic for management of concussion, this exploratory study aimed to further characterize pre-existing patient characteristics and presenting symptoms associated with prolonged recovery. We hypothesized that those with pre-existing mood disturbances and learning disabilities, those presenting with dizziness or loss of consciousness (LOC), those with abnormal near-point convergence and symptom provocation following oculomotor examination, and those with a history of prior concussion and younger age would suffer from prolonged symptoms.

LOC	Loss of consciousness

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Methods

We conducted a retrospective cohort study approved by our institutional review board of patients treated for concussion in the subspecialty sports medicine clinics of a large pediatric tertiary care network. The data were collected via an electronic medical record query. A total of 3740 unique visits for patients age 5-18 years occurred in the clinics between July 1, 2010, and December 31, 2011. A convenience sample of 250 patients, chosen given estimated workload for data abstraction, was randomly selected for further evaluation. All visits for each patient were identified, and charts were abstracted electronically to obtain relevant data. Eligible patients were those who had received a diagnosis of concussion (by *International Classification of Diseases*, *Ninth Revision* codes 850.0, 850.1, 850.11, 850.12, 850.2, 850.3, 850.4, 850.5, or 850.9) by the referring provider. This diagnosis was confirmed by the sports medicine physician at the initial visit using the definition of concussion specified in the Consensus Statement on Concussion in Sport 4th International Conference on Concussion in Sport held in Zurich, Switzerland (mechanism of injury that results in direct or indirect forces to head resulting in symptoms including somatic, cognitive, and emotional disturbances),[20] a 16-point validated symptom scale,[21] and examination findings including balance, neurocognitive deficits, vestibular/oculomotor deficits, and near-point convergence deficits (obtained as a 1-time measure).[22,23] For the majority of patients seen at the clinics, the mechanism of injury is sports-related, although some injuries are trauma-related, including motor vehicle crashes, falls, and playground injuries. Those patients seen with non-sports, trauma-related injuries in the clinic experienced whiplash-type injuries, which were considered to be a low-impact injury mechanism and, therefore, comparable with sports-related concussion. Patients with high-impact, traumatic injury mechanisms (including motor vehicle crashes with patient ejection, death of another passenger, or rollover; and pedestrian/bicyclist without a helmet struck by a motorized vehicle) are not typically seen in our clinic. Patients with intracranial hemorrhage or prior neurologic surgery were excluded; however, those with a pre-existing vestibular disorder, substance abuse, or psychiatric disorder were not excluded. In addition, 3 of the 250 charts were duplicate patients and thus, excluded. The majority of patients seen in the sports medicine clinic are often referred for more severe or prolonged symptoms of concussion from a sports-related injury. There are patients, however, who are seen in the clinic at the time of injury regardless of severity or mechanism. Study data were collected and managed using Research Electronic Data Capture tools hosted at The Children's Hospital of Philadelphia.[24]

Demographics, injury details (date, mechanism), interventions by the referring physician (including recommendation of cognitive rest), initial symptoms at the time of injury, and physical examination findings during the initial patient visit at the sports medicine clinic were all collected from the patient visit record. For school outcomes, data were examined only for patients whose initial injury occurred between September 1 and May 31 in the years 2009, 2010, and 2011. The physical examination is a standardized concussion evaluation performed by the sports medicine physicians at The Sports Medicine and Performance Center at The Children's Hospital of Philadelphia and includes assessment for dysmetria, nystagmus, smooth pursuits, fast saccades (both horizontal and vertical),[25] gaze stability testing, near-point convergence testing,[26] and gait/balance testing. The physical examination, previously published,[22,23] is conducted in a standardized fashion by 3 sports-medicine trained pediatricians. The examination was administered only by these 3 physicians, and was documented in a standardized template in the electronic health record.

Exposures and Outcomes

Patient data were analyzed using 5 categories relating to different types of exposures (ie, potential risk factors) for prolonged recovery: (1) pre-existing conditions on initial presentation, specifically a history of depression, anxiety, attention deficit hyperactivity disorder, and a learning disability, all of which were reported by either patients or parents; (2a) patient- or parent-reported presenting symptoms, specifically dizziness and LOC; (2b) physical examination at the initial clinic visit, specifically symptom provocation following oculomotor examination (with smooth pursuits, saccades or gaze stability testing, or difficulty completing the testing), and abnormal near-point convergence (defined as convergence greater than 6 cm[27,28]); (3) patient age at time of injury; (4) patient- or parent-reported prior history of concussion; and (5) recommendation of cognitive rest by the referring provider (either an athletic trainer, primary care physician, or emergency room physician) prior to initial specialty visit, as ascertained from patient or parent report. During our visits and in our practice, we considered a patient to have a history of a certain condition or be symptomatic by either patient- or parent-report.

The sports medicine subspecialty group developed a "return to learn" protocol for cognitive rest patterned after the return to play protocol from the Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport held in Zurich, Switzerland.[22,23,29] This protocol begins with no school, homework, reading, or electronics (which includes texting, computers, video games), and gradually adds light reading, followed by schoolwork at home, and then school with accommodations as symptoms improve. Patients were documented to have received cognitive rest when, per patient- or parent-report, the rest prescribed by the referring provider was aligned with this protocol. Because of the retrospective nature of this study, monitoring of such rest was not performed.

For each risk factor category, recovery outcomes examined included time until a patient was symptom-free (as assessed by the treating sports medicine clinician) and time until a patient was fully cleared to participate in sports by the sports medicine clinic. To obtain clearance, patients receive a standard postexertion return-to-play protocol, as described in the most recent Zurich guidelines[20]; patients additionally must be at a full cognitive workload, and have normal vestibular and oculomotor examinations.[22] School-related outcomes included the need for school accommodations prescribed by the specialty clinic (via a standardized letter to the patient's school) at any time during recovery (including homebound education, half-days, full days with breaks, elimination of examinations, examinations with extra time and/or note-cards, and elimination of honors classes); decline in grades reported by students at any time during recovery; and time taken until a student returned to school full-time (without accommodations).

Statistical Analyses

Descriptive statistics included means, ranges, medians, and IQRs. Statistical comparisons to assess the prevalence or timing of outcomes between subsets of patients were conducted with several methods. Dichotomous outcomes were analyzed using logistic regression, except for the rare instance when the exposure was categorical and one of the cells had a zero count. An exact χ^2 test was conducted in those instances. Outcomes classified as times were analyzed using quantile regression given the highly skewed nature of these data and the fact that quantile regression enables valid tests of whether medians are equivalent in this context.[30] The presented results include prevalence values and effect estimates that indicate relative prevalence, equal to the prevalence of a given outcome in the exposed group divided by the prevalence of the outcome in the unexposed group. With both regression methods, a test for trend was conducted in instances where the relationship between the exposure and outcome potentially varied in a dose-response fashion. Also, Kaplan-Meier survival curves were used to determine the number of days until patients had returned to school full-time without accommodations, the number of days until patients were symptom-free, and the number of days until patients were fully cleared to return to all normal activities including sports participation. Survival curves were stratified by categorical risk factors of interest and tested for equivalence using the Peto test. The duration between being injured and first seen in clinic was tested using quintile regression to determine whether it should be controlled for as a potential confounder in the regression models. The analysis was conducted using Stata version 12 (StataCorp, College Station, Texas). As our analysis contained a considerable number of bivariate comparisons, approximately 72, we calculated Bonferroni adjusted P-values and considered $P < .0007$ (ie, .05/72 = .0007) to be statistically significant.

Results

A total of 247 patients were included in the analysis from the initial pool of 250 patient charts (3 charts were of duplicate patients). Information on demographics and outcomes are presented in Table I. For all patients, the median number of days until returning to school part-time or initiation of homebound education was 12 days (IQR 6-21); the median number of days until returning to school full-time without any academic accommodations was 35 days (IQR 11-105); the median time until becoming symptom-free was 64 days (IQR 18-119); and the median time until patients were fully cleared for all activities (including sports participation) was 76 days (IQR 30-153) (Figure).

Table I. Demographics of complete dataset

Characteristics	
All patients	n = 247
Injured September 1-May 31	n = 207
Age, y (range)	14 (7-18)
Male, %	58
Sports-related injury, n (%)	190 (77%)
Days postinjury at first visit, median (range)	12 (1-730)
Seen for follow-up visits, n (%)	228 (92%)
Fully cleared at initial visit, n (%)	8 (3%)
Currently following up, n (%)	8 (3%)
Days until return to school part-time/initiation of homebound instruction, median (IQR)*,†	12 (6-21)
Days until return to school full-time, median (IQR)*,†	35 (11-105)
Days until symptom-free, median (IQR)*	64 (18-119)
Days until fully cleared, median (IQR)*	76 (30-153)
% Symptomatic for >4 wk, n (%)	211 (73%)
% Requiring school accommodations, n (%)*,†	207 (73%)
% Reporting decline in grades, n (%)*,†	162 (61%)

*Data only included for patients with follow-up visits.
†Data only included for patients injured between September 1 and May 31.

Pre-Existing Conditions

Results regarding pre-existing conditions are shown in Table II. Overall, 20% of patients or parents reported at least 1 pre-existing condition. Patients with anxiety took more than twice as long to be fully cleared compared with those without anxiety (168 days vs 76 days, $P = .001$). Patients with depression took 2.2 times longer than patients without depression to become symptom-free (142

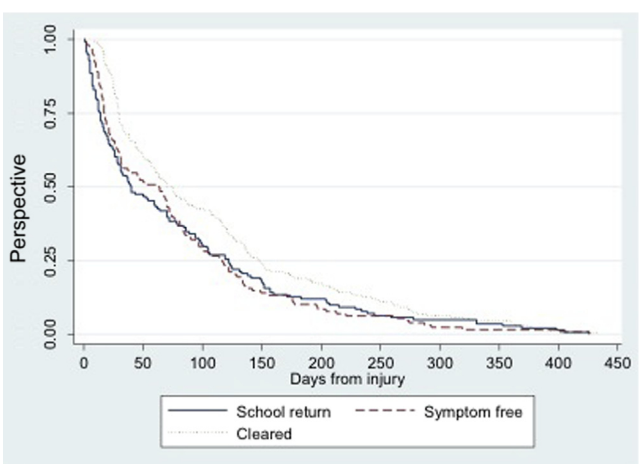

Figure. Survival curves for days until returning to school full-time (without accommodations), time until symptom-free, and time until fully cleared as a function of days from injury.

Table II. Distribution of outcomes by patient pre-existing conditions and presenting signs/symptoms

Pre-existing condition/presenting sign or symptom	All N (%)	Sep-May N (%)	Median days from injury to initial clinic visit	Relative prevalence in exposed vs unexposed group	P	Median days until return to school full-time (IQR)†	Relative prevalence in exposed vs unexposed group	P	Median days until symptom-free (IQR)	Relative prevalence in exposed vs unexposed group	P	Median days until fully cleared (IQR)	Relative prevalence in exposed vs unexposed group	P
Any condition	49 (20%)	35 (17%)	10	0.77	.207	31 (10, 105)	0.97	.962	81 (17, 132)	1.27	.920	75 (29, 205)	0.99	.735
No condition	198 (80%)	172 (83%)	13			32 (12, 113)			64 (19, 116)			76 (30, 150)		
ADHD	22 (9%)	16 (8%)	10	0.83	.580	24 (12, 94)	0.75	.809	61 (14, 200)	0.92	.852	51 (25, 174)	0.65	.482
No ADHD	225 (91%)	191 (92%)	12			32 (11, 106)			66 (19, 117)			78 (30, 152)		
Learn disab	26 (11%)	18 (9%)	10	0.77	.547	37 (10, 100)	1.19	.830	50 (17, 90)	0.76	.565	79 (29, 159)	1.04	.585
No learn disab	221 (89%)	189 (91%)	13			31 (12, 106)			66 (19, 123)			76 (30, 152)		
Depression	15 (6%)	10 (5%)	8	0.62	.135	31 (28, 79)	0.97	.981	142 (31, 274)	2.22	.050	121 (57, 325)	1.61	.006
No depression	232 (94%)	197 (95%)	13			32 (11, 106)			64 (17, 116)			75 (30, 152)		
Anxiety	9 (4%)	7 (3%)	10	0.83	.681	68 (50, 87)	2.13	.987	149 (122, 185)	2.33	.066	168 (71, 304)	2.21	.010
No anxiety	238 (96%)	200 (97%)	12			32 (10, 106)			64 (18, 117)			76 (30, 152)		
Dizziness	161 (66%)	136 (66%)	13	1.08	.643	39 (14, 105)	1.95	.292	70 (21, 122)	2.59	.032	76 (30, 142)	1.06	.961
No dizziness	84 (34%)	71 (34%)	12			20 (7, 79)			27 (14, 112)			72 (28, 182)		
LOC	21 (9%)	19 (9%)	8	0.67	.223	40 (37, 122)	1.38	.650	116 (32, 153)	1.84	.094	102 (70, 137)	1.46	.230
No LOC	223 (91%)	186 (91%)	12			29 (10, 101)			63 (18, 106)			70 (29, 151)		
Oculo abn	126 (74%)	108 (75%)	14	1.08	.725	61 (24, 130)	4.36	.050	74 (25, 134)	3.36	.048	115 (43, 212)	3.03	.003
No oculo abn	45 (26%)	36 (25%)	13			14 (14, 59)			22 (10, 49)			38 (23, 101)		
Abnormal converg	49 (62%)	36 (56%)	10	0.77	.262	47 (23, 118)	1.27	.552	54 (18, 120)	1.64	.178	53 (28, 140)	1.13	.761
Normal converg	30 (38%)	28 (44%)	13			37 (8, 89)			33 (22, 68)			47 (30, 116)		

Pre-existing condition/presenting sign or symptom	% Symptomatic for >4 wk	Relative prevalence in exposed vs unexposed group	P	% Requiring school accommo dations†	Relative prevalence in exposed vs unexposed group	P	% Reporting decline in grades†	Relative prevalence in exposed vs unexposed group	P
Any condition	78%	1.08	.565	73%	1.06	.559	71%	1.16	.339
No condition	72%			69%			61%		
ADHD	74%	1.01	.915	77%	1.12	.440	67%	1.10	.730
No ADHD	73%			69%			61%		
Learn disab	67%	0.92	.519	65%	0.92	.584	85%	1.42	.100
No learn disab	73%			71%			60%		
Depression	87%	1.23	.222	87%	1.26	.165	71%	1.15	.602
No depression	71%			69%			62%		
Anxiety	100%	1.41	.290	100%	1.45	.290	100%	1.64	.391
No anxiety	71%			69%			61%		
Dizziness	77%	1.26	.028	77%	1.38	.001	59%	0.89	.421
No dizziness	61%			56%			66%		
LOC	88%	1.24	.285	71%	1.01	.888	41%	0.65	.152
No LOC	71%			70%			63%		
Oculo abn	80%	1.78	.001	**90%***	**3.00**	**.0001**	65%	1.44	.035
No oculo abn	45%			**39%**			45%		
Abnormal converg	71%	1.13	.927	82%	1.37	.038	71%	0.90	.490
Normal converg	63%			60%			79%		

ADHD, attention deficit hyperactivity disorder; *converg*, convergence; *learn disab*, learning disability; *oculo abn*, symptom provocation following oculomotor examination.
**P* value significant via Bonferroni correction for regression testing (ie, <.0007 [denoted with bold text]).
†Data only included for patients injured between September 1 and May 31.

vs 64 days; $P = .05$) and to be fully cleared (121 vs 75 days; $P = .006$). Patients with depression additionally were prescribed school accommodations more frequently (87% vs 69%; $P = .165$). All patients (100%) with anxiety upon initial presentation, compared with 69% of patients without anxiety, experienced prolongation in symptoms past 4 weeks ($P = .290$). None of the differences observed reached statistical significance using the Bonferroni correction. The median number of days between initial injury and time first seen in clinic did not vary significantly across these patient subgroups, and ranged from 8-14 days.

Presenting Signs and Symptoms

Overall, 66% of patients reported experiencing dizziness immediately following injury, and 9% reported a LOC. Furthermore, 74% had symptom provocation following oculomotor examination on initial clinic physical examination (n = 171), and 62% had abnormal near-point convergence (n = 79, **Table II**). Patients reporting dizziness at the time of injury were more likely than those without dizziness to experience prolongation in symptoms past 4 weeks (77% vs 61%; $P = .028$) and to be prescribed school accommodations (77% vs 56%; $P = .001$). These patients took 2.6 times longer to become symptom-free (70 vs 27 days; $P = .032$). In addition, patients experiencing LOC at the time of injury took 1.8 times longer for symptoms to resolve (116 vs 63 days; $P = .94$), though none of these differences reached statistical significance via the Bonferroni correction.

Patients with symptom provocation following oculomotor examination on initial physical examination were more likely to be prescribed school accommodations (94% vs 36%; $P = .0001^{*}$). They additionally required more time until returning to school full-time (61 vs 14 days; $P = .050$), until becoming symptom-free (74 vs 22 days; $P = .048$), until being fully cleared (115 vs 38 days; $P = .003$), and were more likely to have prolongation of symptoms past 4 weeks (80% vs 45%; $P = .001$) and to report a decline in grades (65% vs 45%, $P = .035$). Finally, patients with abnormal near-point convergence on initial examination were more likely to be prescribed school accommodations than those with normal convergence (82% vs 60%; $P = .038$).

Age

In the examination of patient age (**Table III**), we found that children age 13-14 years took 1.8 times longer (median = 40 days) than the youngest children (age 12 year or younger, median = 22 days) and 15-16 year-old children (median = 35 days) took 1.6 times longer to return to school full-time ($P = .887$ comparing all age groups). We also found children in the youngest age group took nearly twice as long to become symptom-free (78 days for patients less than 12, as opposed to 43 days for patients aged 17-18; $P = .887$ comparing all age groups). Those in the youngest age group were prescribed school accommodations less frequently (57% for those less than 12 vs >70% for all other age groups; $P = .694$ comparing all age groups), and reported a decline in grades less frequently as well (47% for those less than 12 vs 73% for the oldest age group; $P = .553$ among all age groups), although none of these differences reached statistical significance by the Bonferroni correction. A patient- or parent-reported decline in grades functioned in a dose-response fashion, with a decline in grades being more common with increasing age ($P = .0005^{*}$).

History of Prior Concussion

We found substantial variability regarding a history of prior concussion (**Table III**), with the median number of days until being fully cleared ranging from 64 days for those with zero or 1 prior concussion to 243 days for those with 3 or more prior concussions ($P = .0006^{*}$). Those with 2 or more prior concussions took more than twice as long to become symptom-free as those with fewer than 2 (ranging from 45 days for those with no prior concussions to 122 days for those with 3 or more prior; $P = .039$ among all groups). Those with 3 or more prior concussions took 3.6 times longer to return to school full-time compared with those with no prior concussions (105 days for those with 3 or more prior concussions vs 29 days for those with no prior, $P = .187$ among all groups), and the percentage of children who were prescribed school accommodations ranged from 69% for those with no prior concussions to 100% for those with 3 or more prior concussions ($P = .341$ among all groups), though neither of these last 2 values reached statistical significance.

Recommendation of Cognitive Rest by Referring Physician

The referring provider recommended cognitive rest for approximately one-half (54%, n = 138) of all patients (**Table III**). These patients had a prolongation in time until returning to school (40 vs 28 days, $P = .540$), until becoming symptom-free (68 vs 53 days, $P = .569$), and until being fully cleared (100 vs 82 days, $P = .569$), though none of these results reached statistical significance.

Discussion

This study is a comprehensive examination of a large cohort of pediatric patients presenting to a subspecialty clinic for evaluation of concussion. By studying this specific cohort, we have selected a group of patients experiencing the most severe symptoms of concussion to examine possible risk factors for prolonged recovery.

Our data show prolonged recovery times in our population compared with previous studies. Prior studies have estimated healing times after concussion ranging from 14-28 days among the general pediatric population,[10,31] whereas the median time to symptom resolution in our patient sample was 64 days. The recovery times seen in our patients are likely relatively lengthy due to the spectrum bias of this subspecialty referral population with more severe concussions. Even so, our data do suggest that a subset of youth who sustain a concussion experience recovery time longer

Table III. Distribution of outcomes by age, history of prior concussion, and recommendation of cognitive rest

	All N (%)	Sep-May N (%)	Median days from injury to initial clinic visit	Relative prevalence in exposed vs unexposed group	*P*	Median days until return to school full-time (IQR)‡	Relative prevalence in exposed vs unexposed group	*P*	Median days until symptom-free (IQR)	Relative prevalence in exposed vs unexposed group	*P*	Median days until fully cleared (IQR)	Relative prevalence in exposed vs unexposed group	*P*
Age														
17-18	28 (11%)	25 (12%)	9	0.64	.709	19 (10, 66)	0.86	.887	43 (28, 148)	0.55	.887	85 (14, 86)	1.04	.863
15-16	87 (35%)	73 (35%)	12	0.86		35 (11, 101)	1.59		67 (17, 116)	0.86		66 (29, 150)	0.84	
13-14	94 (38%)	81 (39%)	13	0.93		40 (12, 124)	1.82		64 (18, 126)	0.82		79 (31, 156)	0.96	
<12	38 (15%)	28 (14%)	14			22 (10, 47)			78 (26, 123)			82 (33, 195)		
Prior concussions														
≥3	13 (5%)	10 (5%)	19	1.58	.482	105 (85, 291)	3.62	.187	122 (90, 145)	2.71	.039	**243 (116, 385)***	**3.80**	**.0006**
2	22 (9%)	18 (9%)	11	0.92		33 (6, 62)	1.14		99 (55, 141)	2.20		**158 (103, 243)**	**2.47**	
1	55 (22%)	47 (23%)	12	1.00		34 (15, 123)	1.17		53 (20, 122)	1.18		**64 (28, 143)**	**1.00**	
0	157 (64%)	132 (64%)	12			29 (8, 100)			45 (17, 101)			**64 (29, 140)**		
Cognitive rest by referring?‡														
Yes	74 (54%)		12	0.75	.187	40 (20, 133)	1.43	.540	68 (18, 126)	1.28	.569	100 (38, 174)	1.22	.393
No	64 (46%)		16			28 (7, 62)			53 (21, 120)			82 (45, 144)		

	% Symptomatic for >4 wk	Relative prevalence in exposed vs unexposed group	*P*	% Requiring school accommo dations‡	Relative prevalence in exposed vs unexposed group	*P*	% Reporting decline in grades‡	Relative prevalence in exposed vs unexposed group	*P*
Age									
17-18	74%	0.95	.759	72%	1.26	.694	**73%**†	**1.55**	**.553**
15-16	75%	0.96		75%	1.32		**65%**	**1.38**	***.0005***
13-14	69%	0.88		77%	1.35		**58%**	**1.23**	
<12	78%			57%			**47%**		
Prior concussions									
≥3	100%	1.45	.532	100%	1.45	.341	80%	1.36	.5974
2	82%	1.19		67%	0.97		64%	1.08	
1	72%	1.04		83%	1.20		63%	1.07	
0	69%			69%			59%		
Cognitive rest by referring?‡									
Yes	73%	0.94	.309	86%	1.19	.137	67%	1.24	.297
No	78%			72%			54%		

P values reported were derived using regression to compare categorically across groups.
P values reported in italics were derived using regression test for trend, reported only in instances of *P* < .0007.
**P* value significant via Bonferroni for regression testing (ie, <.0007 [denoted with bold text]).
†*P* value significant via Bonferroni for trend test (ie, <.0007 [denoted with bold text]).
‡Data only included for patients injured between September 1 and May 31.

than previously suspected, even without predisposing factors.

Our data show that patients with pre-existing anxiety or depression tend to have a prolonged course compared with those without these pre-existing conditions, specifically regarding resolution of symptoms. There are recent adult data recognizing that attention deficit hyperactivity disorder, depression, and anxiety have important implications in recovery of concussion, and that adults with underlying depression have more severe acute neurocognitive deficits than those without depression[18,19]; in addition, recent studies have demonstrated post-traumatic stress and depression to be important mediators of the relationship between mild traumatic brain injury and health problems in military personnel returning from duty with traumatic brain injury.[32] Few studies, however, have examined these pre-existing conditions in children. Given the common mechanism of neuronal dysfunction underlying mood disorders and traumatic brain injury, it is possible that pre-existing dysfunction may exist and lead to a more difficult recovery; conversely, the cognition dysfunction noted may be secondary to the mood disorder itself rather the traumatic brain injury. Although the direction of causality is still unclear,[9,18] the association remains clinically important.

Our data show that those patients presenting with either dizziness or LOC at the time of initial injury, or found to have either symptom provocation following oculomotor examination or abnormal near-point convergence on initial physical examination at the specialty clinic, have both prolonged symptoms and poorer school outcomes. Prior studies have noted that athletes with migrainous symptoms (including photophobia, nausea, vomiting, and headache), rather than headache alone, have significantly greater neurocognitive deficits when tested.[16,17,33] Even though post-traumatic migraine has become a significant outcome measure in the past several years, at the time of study our group did not use post-traumatic migraine as a measure of recovery, and, therefore, such data were not available for this review. It should be noted that patients specifically with dizziness at the time of injury have been shown to have a higher risk for prolonged recovery,[12] and dizziness itself on initial presentation may signify more severe vestibular deficits in concussion recovery. The data on outcomes for those patients presenting with LOC are more controversial, with several studies showing that LOC, especially lasting less than 1 minute, does not predict symptom severity or duration.[4,5,34] We were unable to stratify patients based on the time of lost consciousness, however, because of the retrospective nature of our study. Finally, although abnormalities in the oculomotor examination have been found to exist beyond the acute phase of concussion,[35] little data exist correlating initial oculomotor deficits or abnormal near-point convergence on physical examination with prolonged recovery or poor school performance. Initial abnormalities in these examination findings may signify more severe cognition dysfunction at the time of injury, and given their importance in completing school tasks, abnormal oculomotor examination and convergence deficits have significant implications in recovery of school performance.

Multiple previous studies comparing high school athletes with college-aged and adult athletes have shown that adolescents are predisposed to prolonged recovery times.[13,14] Previous studies have suggested that patients younger than high school age have prolonged symptoms compared with older teeneagers,[36] however, there have been few formal investigations evaluating recovery time in children younger than age 14. Younger patients, especially those age 12 and younger, had a trend (though not statistically significant) toward prolonged recovery compared with older adolescents in our study, though they did not fare worse on school-related outcomes, possibly because of less rigorous academic demands of children of this age. Although the mechanism of prolonged recovery in the immature brain remains unknown, it has been hypothesized previously that increased susceptibility to neurotransmitter-mediated excitotoxic brain injury is involved.[37] Regardless, further, prospective studies involving stratification of patients by age are needed to delineate these recovery outcomes.

Our patients generally showed a dose-response effect for prolonged recovery and poorer school outcomes with any prior history of concussion. A history of 3 or more previous concussions has been widely reported as a risk factor for prolonged recovery time.[11,38,39] Even though previous studies have shown fewer than 3 prior concussions to not predispose patients to prolonged symptoms,[40] recent data have begun to indicate poorer performance on neurocognitive testing in patients with only one prior injury.[41] Our data show patients with at least 2 prior concussions may be predisposed to poorer outcomes.

Studies have demonstrated greater impairment on neurocognitive testing with early physical and mental activity,[42,43] making cognitive rest a mainstay in the clinical treatment of concussion.[44,45] However, empiric data supporting the use of cognitive rest in concussion are conflicting. One study showed no association between recommendation of cognitive rest and length of symptoms,[46] and another showed improved performance on cognitive testing and decreased symptom reporting with any cognitive rest.[47] We found that the recommendation of cognitive rest did not influence outcomes, though we have difficulty drawing conclusions from our data, as the cognitive rest experienced by our patients was neither homogenous nor prescribed in a standardized fashion. As cognitive rest is topic of great interest, it was included in this descriptive, exploratory study. Based on prior studies showing that peak symptomatology from concussion to occur at 7 days,[26,48] as well as our own clinical experience, we hypothesize that the timing of cognitive rest may be important; early rest in concussion may be beneficial, whereas prolonged cognitive rest may not. This hypothesis must be tested with prospective data collection in a sample more representative of all youth concussion patients.

Our findings cannot be generalized to concussion in all populations, as our focus was on a subspecialty referral population in a sports medicine clinic. Presumably, those with less severe injuries would be initially seen, treated, and recover without necessitating specialist referral. In addition, our findings cannot be extrapolated to those patients with high-impact injury mechanisms, as such patients are not typically evaluated in the sports medicine clinics. As this was a referral population, a gap existed (median 12 days) between the patient's injury and initial specialty visit, which led to variability in the physical examination findings observed at the initial visit. The duration between being injured and first seen in clinic was found to not vary across categories of the variables treated as exposures (**Tables II** and **III**), thus, obviating the need to control for this duration as a potential confounder in the regression models.[49] The fact that we only examined data in a single care network also limits the generalizability of our study as other networks may have different patterns of care.

As our study was a retrospective chart review, there were limitations on our ability to standardize outcomes, specifically those that relied on patient- or parent-report (cognitive rest, pre-existing conditions, prior concussion history, and symptomatology), provider assessments (physical examination findings), and accommodations used by schools, thereby introducing the influence of recency effect and recall bias into our data. We did not collect baseline physical examination findings for our patients, and theoretically any physical examination abnormalities, specifically vestibular deficits in patients with pre-existing neurologic or psychological disorders, may have been a pre-existing finding unrelated to acute injury. In addition, for our physical examination, we only obtained near-point convergence as a 1-time measure; other clinics have taken the approach of averaging 3 separate measures.[50]

There was variability in the number of patients contributing to any given analysis, because of a combination of unavailable data secondary to documentation, patients lost to follow-up, and patients who continued to receive treatment and had unresolved symptoms. As such, and given the sample size of 247 patients in total, the power to detect differences across patient subgroups was often low. We observed multiple instances where recovery outcomes differed notably between subsets of patients to an extent that might be clinically meaningful but was not significant statistically via either standard measures or by the Bonferroni correction. Had studies previously reported characteristics of similar patient populations, we could have used those findings to estimate the sample size we would require to expect adequate power to test our hypothesis. Given that no such reports exist, we enrolled a convenience sample of a size that was feasible and reasonable for calculating the prevalence estimates that we have reported here. Thus, one additional contribution of our study is providing prevalence estimates that can be used to plan sample size and power issues for future studies. As in any study with tests of significance, our results should be interpreted with consideration of whether the magnitude of differences that was observed reaches levels that are clinically meaningful. ■

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References

1. Meehan WP III, Mannix R. Pediatric concussions in United States emergency departments in the years 2002 to 2006. J Pediatr 2010;157:889-93.
2. Schatz P, Moser RS. Current issues in pediatric sports concussion. Clin Neuropsychol 2011;25:1042-57.
3. Moser RS. The growing public health concern of sports concussion: the new psychology practice frontier. Prof Psychol Res Pract 2007;38:699-704.
4. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. Clin J Sport Med 2003;13:222-9.
5. Grady MF. Concussion in the adolescent athlete. Curr Probl Pediatr Adolesc Health Care 2010;40:154-69.
6. Bakhos LL, Lockhart GR, Myers R, Linakis JG. Emergency department visits for concussion in young child athletes. Pediatrics 2010; 126:550-6.
7. Collins MW, Field M, Lovell MR, Iverson G, Johnston KM, Maroon J, et al. Relationship between post-concussion headache and neuropsychological test performance in high school athletes. Am J Sports Med 2003; 31:168-73.
8. Iverson GL, Gaetz M, Lovell MR, Collins MW. Relation between subjective fogginess and neuropsychological testing following concussion. J Int Neurospych Soc 2004;10:904-6.
9. Sigurdardottir S, Andelic N, Roe C, Jerstad T, Schanke AK. Post-concussion symptoms after traumatic brain injury at 3 and 12 months post-injury: a prospective study. Brain Inj 2009;23:489-97.
10. Eisenberg MA, Andrea J, Meehan WP III, Mannix R. Time Interval Between Concussions and Symptom Duration. Pediatrics 2013;132:8-17.
11. Iverson GL, Gaetz M, Lovell MR, Collins MW. Cumulative effects of concussion in amateur athletes. Brain Inj 2004;18:433-43.
12. Lau BC, Kontos AP, Collins MW, Mucha A, Lovell MR. Which on-field signs/symptoms predict protracted recovery from sports-related concussion among high school football players? Am J Sports Med 2011;39:2311-8.
13. Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. J Pediatr 2003;142:546-53.
14. Sim A, Terryberry-Spohr L, Wilson KR. Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes. J Neurosurg 2008;108:511-6.
15. 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. JAMA Pediatr 2013;167:156-61.
16. Mihalik JP, Register-Mihalik J, Kerr ZY, Marshall SW, McCrea MC, Guskiewicz KM. Recovery of posttraumatic migraine characteristics in patients after mild traumatic brain injury. Am J Sports Med 2013;41: 1490-6.
17. Kontos AP, Elbin RJ, Lau B, Simensky S, Freund B, French J, et al. Posttraumatic migraine as a predictor of recovery and cognitive impairment after sport-related concussion. Am J Sports Med 2013;41:1497-504.
18. Kutcher JS, Eckner JT. At risk populations in sports related concussion. Curr Sports Med Rep 2010;9:16-20.
19. Preece MH, Geffen GM. The contribution of pre-existing depression to the acute cognitive sequelae of mild traumatic brain injury. Brain Inj 2007;21:951-61.

20. McCrory P, Meeuwisse W, Aubry M, Cantu B, Dvorak J, Echemendia R, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med 2013;47:250-8.
21. Piland SG, Motl RW, Ferrar MS, Peterson CL. Evidence for the factorial and construct validity of a self-report concussion symptoms scale. J Athl Train 2003;38:104-12.
22. Master CL, Grady MF. Office-based management of pediatric and adolescent concussion. Pediatr Ann 2012;41:1-6.
23. Master CL, Balcer L, Collins M. Concussion. Ann Intern Med 2014;160. ITC2-1.
24. 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;42:377-81.
25. Thiagarajan P, Ciuffreda KJ. Visual fatigue and accommodative dynamics in asymptomatic individuals. Optom Vis Sci 2013;90:57-65.
26. Lavrich JB. Convergence insufficiency and its current treatment. Curr Opin Ophthalmol 2010;21:356-60.
27. Hayes GJ, Cohen BE, Rouse MW, DeLand PN. Normative values for the nearpoint convergence of elementary schoolchildren. Optom Vis Sci 1998;75:506-12.
28. Bade A, Boas M, Gallaway M, Mitchell GL, Scheiman M, Kulp MT. Relationship between clinical signs and symptoms of convergence insufficiency. Optom Vis Sci 2013;90:988-95.
29. McCrory P, Meeuwisse W, Johnston K, Dvorak J, Aubry M, Molloy M, et al. Consensus statement on concussion in sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. Br J Sports Med 2009;43(Suppl 1):i76-90.
30. Chamberlain G. Quantile regression, censoring, and the structure of wages. In: Cims CA, ed. Advances in Econometrics, Vol. 1: Sixth World Congress. Cambridge: Cambridge University Press; 1994. p. 171-209.
31. McClincy MP, Lovell MR, Pardini J, Collins MW, Sporeb MK. Recovery from sports concussion in high school and collegiate athletes. Brain Inj 2006;20:33-9.
32. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild traumatic brain injury in U.S. soldiers returning from Iraq. N Engl J Med 2008;358:453-63.
33. Reddy CC, Collins MW. Sports concussion: management and predictors of outcome. Curr Sports Med Rep 2009;8:10-5.
34. Erlanger D, Kaushik T, Cantu R, Barth JT, Broshek DK, Freeman JR, et al. Symptom-based assessment of the severity of a concussion. J Neurosurg 2003;98:477-84.
35. Capo-Aponte JE, Urosevich TG, Temme LA, Tarbett AK, Sanghera NK. Visual dysfunctions and symptoms during the subacute stage of blast-induced mild traumatic brain injury. Mil Med 2012;177:804-13.
36. Blinman TA, Houseknecht E, Snyder C, Nance ML. Postconcussive symptoms in hospitalized pediatric patients after mild traumatic brain injury. J Pediatr Surg 2009;44:1223-8.
37. Grundl PD, Biagas KV, Kochanek PM, Schiding JK, Barmada MA, Nemoto EM. Early cerebrovascular response to head injury in immature and mature rats. J Neurotrauma 1994;11:135-48.
38. Theriault M, De Beaumont L, Tremblay S, Lassonde M, Jolicoeur P. Cumulative effects of concussions in athletes revealed by electrophysiological abnormalities on visual working memory. J Clin Exp Neuropsychol 2011;33:30-41.
39. Schatz P, Moser RS, Covassin T, Karpf R. Early indicators of enduring symptoms in high school athletes with multiple previous concussions. Neurosurgery 2011;68:1562-7.
40. Iverson GL, Brooks BL, Lovell MR, Collins MW. No cumulative effects for one or two previous concussions. Br J Sports Med 2006;40:72-5.
41. Colvin AC, Mullen J, Lovell MR. The role of concussion history and gender in recovery from soccer-related concussion. Am J Sports Med 2009;37:1699-704.
42. Majerske CW, Mihalik JP, Ren D, Collins MW, Reddy CC, Lovell MR, et al. Concussion in sports: postconcussive activity levels, symptoms, and neurocognitive performance. J Athl Train 2008;43:265-74.
43. Brown NJ, Mannix RC, O'Brien MJ, Gostine D, Collins MW, Meehan WP III. Effect of cognitive activity level on duration of post-concussion symptoms. Pediatrics 2014;133:299-304.
44. McCrory P, Meeuwisse W, Johnston K, Dvorak J, Aubry M, Molloy M, et al. Consensus statement on concussion in sport: the 3rd international conference on concussion in sport held in Zurich, November 2008. PM R 2009;1:406-20.
45. Atabaki SM. Updates in the general approach to pediatric head trauma and concussion. Pediatr Clin North Am 2013;60:1107-22.
46. Gibson S, Nigrovic LE, O'Brien M, Meehan WP III. The effect of recommending cognitive rest on recovery from sport-related concussion. Brain Inj 2013;27:839-42.
47. Moser RS, Glatts C, Schatz P. Efficacy of immediate and delayed cognitive and physical rest for treatment of sports-related concussion. J Pediatr 2012;161:922-6.
48. Kontos AP, Elbin RJ, Schatz P, Covassin T, Henry L, Pardini J, et al. A revised factor structure for the post-concussion symptom scale: baseline and post-concussion factors. Am J Sports Med 2012;40:2375-84.
49. Rothman KJ, Greenland S. Precision and validity in epidemiologic studies. In: Rothman KJ, Greenland S, eds. Modern epidemiology. 2nd ed. Philadelphia, PA: Lippincott Williams and Wilkins; 1998. p. 123-5.
50. Scheiman M, Cotter S, Kulp MT, Mitchell GL, Cooper J, Gallaway M , et al., Convergence Insufficiency Treatment Trial Study Group. Treatment of accommodative dysfunction in children: results from a randomized clinical trial. Optom Vis Sci 2011;88:1343-52.