Psychosocial and Executive Function Recovery Trajectories One Year after Pediatric Traumatic Brain Injury: The Influence of Age and Injury Severity

Heather T. Keenan,¹ Amy E. Clark,¹ Richard Holubkov,¹ Charles S. Cox,² and Linda Ewing-Cobbs³

Abstract

Time since traumatic brain injury (TBI) and developmental stage at injury may affect the trajectory of outcomes associated with adjustment and school success. We prospectively enrolled a cohort of 519 children with either TBI or orthopedic injury (OI) age 2.5–15 years to examine children's psychosocial and executive function outcomes at 3- and 12-months post-injury. Outcome measures included the Child Behavior Checklist (CBCL), Strengths and Difficulties Questionnaire (SDQ), and Behavior Rating Inventory of Executive Function (BRIEF) ratings. Controlling for pre-injury ratings and using the OI group as the reference, children with TBI, regardless of age or injury severity, had affective, anxiety, and attention-deficit/hyperactivity disorder (ADHD) problems on the CBCL. Symptom trajectories differed both by injury severity and age at injury. Children with mild and complicated mild TBI had a decreasing anxiety trajectory, whereas children with severe TBI had increasing symptoms. Children 6–11 years of age had high ADHD and affective scores; however, the youngest children had increasing symptoms over time. On the SDQ, peer relationships and prosocial behaviors were not significantly affected by TBI but were associated with family environment. Children with severe TBI had the worst executive function scores; however, mild and complicated mild/moderate TBI groups had clinically important working memory deficits. Hispanic ethnicity and strong social capital were positively associated with multiple outcomes. Children's recovery trajectories differed by injury severity, time since injury, and developmental stage when injured. Schools need to reassess children's skills over time as new problems in behavior and learning may emerge.

Keywords: cohort; pediatrics; trauma; traumatic brain injury

Introduction

TRAUMATIC BRAIN INJURY (TBI) in children occurs in a setting of rapid developmental, physical, cognitive, emotional, and social growth. Children recovering from TBI must not only recover to their former level of functioning, but also must learn new skills to keep developmentally on track.¹ Social expectations for behavior regulation and emotional control rapidly increase as children age. TBI may disrupt core abilities that support social, emotional, and cognitive performance required to make and retain friends and function at home and in school.² Longitudinal follow-up of children is important, as prior studies have shown that children may initially appear to be on track with their peers after TBI, but subsequently fall behind in some areas as demands for new skills increase.^{3,4}

Although children's recovery after TBI is affected by injury severity and the child's personal reserve, recovery takes place within the larger environment of family, school, and community as reflected in the International Classification of Functioning, Disability and

Health's (ICFDH) model of disability.⁵ The family environment including family structure, functioning, and financial and social resources may moderate developmental outcomes allowing some children to maximize their gains after injury.^{6,7}

This prospective cohort study was assembled to longitudinally examine children's development after injury. We examined the impact of TBI severity, age at injury, and time since injury on psychosocial and executive functions during the first year after TBI relative to an orthopedic injury (OI) comparison group. Consistent with the ICFDH model, we expected that family environment would significantly influence these outcomes.

Methods

Patient population

Patients were children injured between 2.5 and 15 years of age, recruited from two level 1 pediatric trauma centers, Primary Children's Hospital (PCH) in Salt Lake City, UT, and University of

¹Department of Pediatrics, University of Utah, Salt Lake City, Utah.

²Department of Pediatric Surgery, University of Texas Medical School at Houston, Houston, Texas.

³Department of Pediatrics and Children's Learning Institute, University of Texas Health Science Center at Houston, Houston, Texas.

Texas Health Science Center at Houston (UTHealth). PCH is the sole level 1 pediatric trauma center in the Intermountain West and serves a five-state area. UTHealth serves the Houston metropolitan region and surrounding area. Children sustaining either TBI or OI were recruited from both the Emergency Department (ED) and inpatient units of both hospitals. Children were recruited from January 20, 2013, through September 30, 2015, in two ways: families either were approached in person in the ED or hospital (PCH and UTHealth) or contacted by telephone after review of ED logs (UTHealth). Children were recruited sequentially according to child age, injury type, and TBI severity to ensure adequate representation in all age and injury group strata. Child age groups (2.5 to 5 years; 6 to 11 years; 12 to <16 years) were chosen to reflect pre-school, school-age, and adolescent developmental stages. Children with severe developmental delay or severe psychiatric disorders, defined as requiring a self-contained educational program, were excluded because of the difficulty in measuring effect of injury. Institutional review board approval was obtained from both the University of Utah and UTHealth.

Definitions

Traumatic brain injury group. TBI was defined according to the Centers for Disease Control (CDC) 2002 report as an injury to the head with observed or reported decreased level of consciousness, amnesia, and/or neuropsychological abnormality or diagnosed intracranial lesion.⁸ TBI severity was measured by the ED Glasgow Coma Scale (GCS).⁹ TBI severity was divided into three categories: mild, moderate, and severe. Mild TBI was defined according to CDC and World Health Organization (WHO) definitions as a GCS score of 13 or higher upon presentation to healthcare with a GCS score of 15 at discharge or after 24 h if hospitalized, and one or more focal signs including a period of transient confusion, loss of consciousness for 30 min or less, post-traumatic amnesia for less than 24 h, and/or transient neurological abnormalities.^{10,11} Children with mild TBI were subclassified as complicated mild or mild based on the presence or absence of an intracranial hemorrhage diagnosed on computed tomography (CT) scan. Moderate TBI was categorized as an ED GCS score of 9–12. Severe TBI was categorized as an ED GCS score of 3–8.

Orthopedic injury comparison group. Children with an upper or lower extremity long bone fracture and no head injury were recruited contemporaneously with the TBI group. OI com-

parisons were used to isolate the effect of TBI from the effect of being injured, and to account for pre-injury differences among injured versus uninjured children. Injury severity was measured with the Abbreviated Injury Scale (AIS).¹² Forty children with OI were recruited for each age group.

Data sources

As soon as possible after injury, parents or guardians (who we will refer to as parents) were asked to complete a survey that included family demographic information such as family composition, self-identified race and ethnicity, family income category, parental education and employment, and health insurance status. Parents completed pre-injury measures of child outcomes, family functioning, and social support. Follow-up assessments were collected at 3 and 12 months. For English-speaking families, pre-injury and follow-up assessments were completed in person, online, or by telephone. Spanish-speaking families were interviewed in person or by telephone by bilingual study coordinators.

Medical records were abstracted for clinical and injury mechanism data by trained study coordinators using a standardized data abstraction form. Trauma registrars at each institution assigned the AIS scores. CT scans were performed for clinical indication only and were read by pediatric neuroradiologists at each site. CT reports were used to subclassify the mild TBI children.

Measures

Outcomes. We chose three well-validated parent report measures recommended by the National Institute of Neurologic Disorders and Stroke common data elements for TBI to examine psychosocial and executive function outcomes.¹³

Strengths and Difficulties Questionnaire (SDQ).¹⁴ The SDQ is a 25-item behavioral screening questionnaire for children age 4–17 years. The SDQ has five subscales: emotional symptoms, conduct problems, hyperactivity, peer problems, and prosocial behavior. Items for each scale are summed to generate a score of 0–10. The first four subscales are added to calculate a total difficulties score (0–40) with higher numbers representing more problems. For the prosocial scale, higher numbers represent better outcomes. Test-retest reliability ($r=0.76$) and internal consistency (Cronbach's $\alpha=0.80$) are adequate.¹⁵

FIG. 1. Flow diagram of cohort recruitment.

TABLE 1. CHILD, FAMILY, AND INJURY CHARACTERISTICS BY INJURY SEVERITY

	<i>Mild TBI</i> (n = 144)	<i>Complicated mild TBI</i> (n = 130)	<i>Moderate TBI</i> (n = 26)	<i>Severe TBI</i> (n = 86)	<i>TBI overall</i> (n = 386)	<i>Orthopedic</i> (n = 133)
<i>Child and family characteristics</i>						
Enrollment site ^a : Utah	85 (59%)	80 (62%)	11 (42%)	50 (58%)	226 (59%)	75 (56%)
Prefer to complete surveys online	98 (68%)	107 (82%)	14 (54%)	59 (69%)	278 (72%)	102 (77%)
Preferred language ^a : Spanish	18 (13%)	7 (5%)	3 (12%)	13 (15%)	41 (11%)	19 (14%)
Age (years) ^a : mean (SD)	9.1 (4.3)	9.4 (4.3)	8.4 (4.0)	9.1 (4.2)	9.2 (4.2)	8.6 (4.1)
Child sex ^a : Female	56 (39%)	41 (32%)	18 (69%)	24 (28%)	139 (36%)	49 (37%)
Child race ^{a,b}						
American Indian or Alaska Native	2 (1%)	0 (0%)	0 (0%)	1 (1%)	3 (1%)	0 (0%)
Asian	1 (1%)	4 (3%)	1 (4%)	0 (0%)	6 (2%)	2 (2%)
Black or African American	13 (9%)	4 (3%)	5 (20%)	6 (7%)	28 (7%)	10 (8%)
Native Hawaiian or other Pacific Islander	2 (1%)	1 (1%)	0 (0%)	2 (2%)	5 (1%)	0 (0%)
Caucasian	112 (78%)	108 (84%)	18 (72%)	70 (83%)	308 (81%)	106 (81%)
Mixed	13 (9%)	12 (9%)	1 (4%)	5 (6%)	31 (8%)	13 (10%)
Child ethnicity ^{a,b} : Hispanic or Latino	36 (25%)	25 (20%)	8 (31%)	28 (33%)	97 (25%)	39 (29%)
Respondent sex: Female	109 (76%)	91 (70%)	24 (92%)	64 (74%)	288 (75%)	101 (76%)
Contact caregiver						
Mother	125 (87%)	114 (88%)	23 (88%)	72 (84%)	334 (87%)	107 (80%)
Father	14 (10%)	13 (10%)	1 (4%)	10 (12%)	38 (10%)	23 (17%)
Other	5 (3%)	3 (2%)	2 (8%)	4 (5%)	14 (4%)	3 (2%)
Married ^b	104 (73%)	104 (81%)	12 (46%)	57 (66%)	277 (72%)	90 (69%)
Either caregiver currently employed	134 (93%)	125 (96%)	20 (77%)	76 (88%)	355 (92%)	117 (88%)
Respondent education ^{a,b}						
Less than high school	21 (15%)	8 (6%)	5 (19%)	17 (20%)	51 (13%)	20 (15%)
High school	35 (24%)	20 (16%)	9 (35%)	25 (29%)	89 (23%)	16 (12%)
Vocational/Some college	46 (32%)	68 (53%)	7 (27%)	27 (31%)	148 (38%)	48 (36%)
Bachelor's degree or higher	42 (29%)	33 (26%)	5 (19%)	17 (20%)	97 (25%)	49 (37%)
Income at or below poverty level ^{a,b}	44 (33%)	16 (14%)	14 (58%)	20 (26%)	94 (27%)	30 (23%)
Family receives financial assistance ^b	54 (38%)	31 (24%)	11 (42%)	30 (35%)	126 (33%)	44 (34%)
Insurance type ^b						
None	12 (8%)	13 (10%)	4 (15%)	10 (12%)	39 (10%)	8 (6%)
Medicaid/CHIP	54 (38%)	39 (30%)	13 (50%)	34 (40%)	140 (36%)	43 (32%)
Commercial/Private/Military	78 (54%)	77 (60%)	9 (35%)	42 (49%)	206 (54%)	82 (62%)
Problematic family functioning ^a (score >2)	17 (12%)	15 (12%)	5 (19%)	10 (12%)	47 (12%)	14 (11%)
Social capital index ^{a,b} : mean (SD)	3.5 (1.1)	3.6 (1.0)	3.1 (1.2)	3.4 (1.0)	3.5 (1.0)	3.6 (1.0)
<i>Injury characteristics</i>						
Admission type						
ED/OBS only	69 (48%)	7 (5%)	2 (8%)	1 (1%)	79 (20%)	91 (68%)
Hospital but not PICU	57 (40%)	59 (45%)	3 (12%)	0 (0%)	119 (31%)	41 (31%)
PICU	18 (13%)	64 (49%)	21 (81%)	85 (99%)	188 (49%)	1 (1%)
Injury mechanism						
Pedestrian or bicycle	23 (16%)	16 (12%)	2 (8%)	16 (19%)	57 (15%)	5 (4%)
Motorized vehicle	35 (24%)	28 (22%)	13 (50%)	52 (60%)	128 (33%)	10 (8%)
Fall	61 (42%)	66 (51%)	7 (27%)	9 (10%)	143 (37%)	98 (74%)
Struck by or against	13 (9%)	11 (8%)	1 (4%)	5 (6%)	30 (8%)	7 (5%)
Organized sport	10 (7%)	5 (4%)	0 (0%)	2 (2%)	17 (4%)	11 (8%)
Other: animal injury	2 (1%)	3 (2%)	2 (8%)	1 (1%)	8 (2%)	2 (2%)
Other	0 (0%)	1 (1%)	1 (4%)	1 (1%)	3 (1%)	0 (0%)
Intentional injury	0 (0%)	1 (1%)	1 (4%)	0 (0%)	2 (1%)	0 (0%)
Lowest ED GCS after resuscitation						
GCS Motor: median (Q1, Q3)	6 (6, 6)	6 (6, 6)	5 (5, 5)	1 (1, 4)	6 (5, 6)	—
GCS Total: median (Q1, Q3)	15 (15, 15)	15 (14, 15)	10 (10, 11)	3 (3, 6)	15 (10, 15)	—
Which extremity was fractured?						
Arm	—	—	—	—	—	92 (69%)
Leg	—	—	—	—	—	39 (29%)
Both	—	—	—	—	—	2 (2%)
Head and neck AIS: median (Q1, Q3)	1 (1, 3)	3 (3, 3)	3 (2, 4)	4 (3, 5)	3 (2, 3)	0 (0, 0)
Other area injured aside from head	76 (53%)	95 (73%)	24 (92%)	79 (92%)	274 (71%)	133 (100%)

(continued)

TABLE 1. (CONTINUED)

	Mild TBI (n = 144)	Complicated mild TBI (n = 130)	Moderate TBI (n = 26)	Severe TBI (n = 86)	TBI overall (n = 386)	Orthopedic (n = 133)
Maximum AIS						
Any body region: median (Q1, Q3)	2 (1, 3)	3 (3, 3)	3 (2, 4)	4 (3, 5)	3 (2, 3)	2 (2, 2)
Excluding head ^a : median (Q1, Q3)	1 (0, 2)	1 (0, 1)	2 (1, 2)	2 (1, 3)	1 (0, 2)	2 (2, 2)
Injury severity score: median (Q1, Q3)	5 (1, 10)	10 (9, 16)	10 (8, 21)	22 (14, 29)	10 (5, 17)	4 (4, 5)
Head imaging in ED (CT)	125 (87%)	130 (100%)	26 (100%)	86 (100%)	367 (95%)	–

^aVariable was selected a priori for consideration in outcome modeling. In outcome models, poverty level, family function, Social Capital Index, and maximum AIS were treated as continuous variables.

^bMissing values were excluded from summary statistics.

AIS, Abbreviated Injury Score; CT, computed tomography; ED, emergency department; GCS, Glasgow Coma Scale; OBS, observation unit; PICU, pediatric intensive care unit; SD, standard deviation; TBI, traumatic brain injury.

– Data were not collected or are not applicable for the injury group.

Q1: 25th percentile; Q3: 75th percentile.

Child Behavior Checklist (CBCL).¹⁶ The CBCL is a parent report questionnaire assessing internalizing and externalizing behaviors. We used the *Diagnostic and Statistical Manual* (DSM) oriented ADHD, affective disorder, and anxiety disorder scales from both the 1.5–5 year and 6–18 year forms. Each subscale provides a T-score normed for age and sex. The CBCL has excellent test-retest reliability ($r=0.7$ – 0.8) and internal consistency ($\alpha=0.90$ – 0.94) at one year.

Behavior Rating Inventory of Executive Function (BRIEF).¹⁷ The BRIEF, a parent rating of everyday executive skills involved in behavioral regulation and metacognition, has high test-retest reliability (0.82 – 0.88). We assessed the inhibit, emotional control, working memory, and plan/organize scales and the metacognition index. The BRIEF pre-school version (BRIEF-P) for children 1.5–5 years provides the same scales as well as inhibitory self-control and the emergent metacognitive index. T-scores are based on normative data for age and sex.

Family environment covariates. Pre-injury family function was assessed using the McMaster Family Assessment Device (FAD)–General Functioning Scale.¹⁸ The FAD includes 12 items scored 1–4 with higher scores representing worse functioning. The Social Capital Index measures a person's connection to their community including perceptions of personal, family, neighborhood, and spiritual community support.¹⁹ The index provides a total score with higher scores representing more support. Families self-reported their income category by family size, from which their poverty level was calculated using federal norms.

Statistical analysis

All children with evaluable outcomes pre-injury and at either the 3- or 12-month time-point were included in the analysis. Due to small numbers of children with moderate TBI, the moderate and complicated mild groups were combined for modeling based on prior studies showing similar outcomes.²⁰ Generalized linear mixed models, with an unstructured covariance matrix and using the Kenward-Roger approach for testing significance of fixed effects, were fit for each outcome using SAS PROC MIXED. Potentially clinically important covariates selected a priori were initially evaluated in a model controlling for pre-injury score, injury group, time, and injury group-by-time interaction. To develop the final reported models, a “full model” including all candidate covariates with $p < 0.15$ in initial screening and these same four factors was iteratively reduced by removal of covariates/factors (excluding pre-injury score and main effects of injury and time) with $p > 0.1$.

Results

Study population

Consent was provided to participate in the study for 639 children injured between 2.5 and 15 years of age. Of those, 584 (91%) completed the pre-injury assessment and 519 (81%) also completed either a 3- or 12-month assessment; the latter group comprises the cohort. Of these 519 children, 438 (84%) completed both follow-up assessments, whereas 46 (9%) completed only the 3-month and 35 (7%) completed only the 12-month assessment (Fig. 1).

The cohort consisted of 144 (28%) children with mild TBI, 130 (25%) with complicated mild TBI (25%), 26 (5%) with moderate TBI, and 86 (17%) with severe TBI. There were 133 (26%) children with OI: 92 (69%) arm; 39 (29%) leg; and 2 (2%) both. Table 1 provides the cohort's demographic and injury variables.

Whereas the Utah site enrolled more participating children (58%), enrollment sites did not differ by injury type or severity. Most families completed assessments via the web (73%) and in the English language (88%). Injury groups had similar distributions of child sex, race/ethnicity, preferred language, and insurance status. Respondent education differed by injury severity, with lower educational achievement seen in the moderate and severe TBI groups. Pre-injury ratings of family environment covariates were similar between injury groups.

Falls were the most frequent injury mechanism ($n=241$, 46%) and the primary mechanism of injury for the orthopedic group (74%), mild TBI (42%), and complicated mild TBI (51%) groups. Motorized vehicle crashes as passenger or pedestrian/cyclist ($n=138$, 27%) were the second most frequent injury mechanism and were responsible for over half of the moderate and severe TBI. Compared with children with mild or complicated mild TBI, children with moderate or severe TBI were more likely to have an injury of AIS ≥ 2 to a body region other than the head.

Pre-injury ratings on the BRIEF, BRIEF-P, SDQ, and CBCL scales did not differ by injury group except for BRIEF working memory, which was higher in the mild TBI group. Mean scores were in the typical range in all areas (Table 2).

Psychosocial outcomes

Strengths and Difficulties Questionnaire. SDQ model results are displayed in Table 3. After adjustment for baseline functioning, children with severe injuries had higher predicted scores indicating more problems on the total difficulties scale. Specifically, children with severe TBI had a 2.4-point higher total difficulties

TABLE 2. UNADJUSTED OUTCOMES OVER TIME

	Mild TBI (n = 144)			Complicated mild/moderate TBI (n = 156)			Severe TBI (n = 86)			Orthopedic (n = 133)		
	Pre-injury mean (SD)	3 month mean (SD)	12 month mean (SD)	Pre-injury mean (SD)	3 month mean (SD)	12 month mean (SD)	Pre-injury mean (SD)	3 month mean (SD)	12 month mean (SD)	Pre-injury mean (SD)	3 month mean (SD)	12 month mean (SD)
Strengths and Difficulties Questionnaire^a												
Emotional symptoms	1.6 (2.0)	1.9 (2.0)	1.8 (2.1)	1.6 (2.1)	2.3 (2.4)	1.8 (2.0)	1.3 (1.3)	2.0 (2.2)	1.7 (2.0)	1.3 (1.4)	1.2 (1.4)	1.4 (1.9)
Conduct problems	1.5 (1.9)	1.7 (2.0)	1.7 (2.3)	1.1 (1.5)	1.5 (1.8)	1.6 (2.0)	1.1 (1.3)	1.7 (1.9)	1.7 (1.5)	1.2 (1.5)	1.1 (1.1)	1.3 (1.8)
Hyperactivity	3.2 (2.7)	3.3 (2.7)	3.5 (2.8)	2.8 (2.4)	3.5 (2.7)	3.2 (2.6)	3.0 (2.7)	4.1 (2.7)	3.3 (2.5)	2.7 (2.2)	2.6 (2.1)	2.6 (2.0)
Peer problems	1.6 (1.6)	1.7 (1.8)	1.7 (1.7)	1.3 (1.6)	1.4 (1.5)	1.6 (1.7)	1.2 (1.4)	1.7 (1.9)	1.8 (1.9)	1.3 (1.5)	1.5 (1.5)	1.5 (1.9)
Prosocial	8.6 (1.8)	8.0 (2.0)	7.8 (2.6)	8.5 (1.9)	7.7 (2.2)	7.8 (2.4)	8.5 (1.7)	7.9 (2.0)	7.8 (2.2)	8.2 (2.1)	7.8 (2.2)	8.2 (2.1)
Total difficulties	7.8 (6.6)	8.5 (6.5)	8.7 (7.0)	6.8 (5.7)	8.7 (6.4)	8.3 (6.6)	6.6 (5.3)	9.5 (6.6)	8.6 (5.9)	6.5 (4.8)	6.5 (4.4)	6.7 (5.8)
Child Behavior Checklist												
ADHD	54.9 (7.1)	55.6 (7.4)	55.6 (7.2)	53.7 (5.6)	54.9 (6.5)	54.7 (7.1)	54.3 (6.2)	55.7 (7.9)	56.5 (7.7)	53.9 (5.9)	52.8 (5.2)	53.0 (5.3)
Affective disorder	54.9 (7.3)	56.4 (8.3)	55.3 (7.3)	53.8 (5.9)	57.1 (8.7)	56.2 (8.5)	53.8 (5.5)	56.7 (7.6)	57.7 (8.6)	53.7 (5.7)	53.4 (5.6)	53.8 (6.1)
Anxiety disorder	53.4 (6.1)	55.0 (7.8)	53.7 (6.7)	53.5 (6.3)	56.1 (8.2)	54.8 (7.9)	53.2 (5.2)	54.9 (6.5)	56.3 (7.5)	53.6 (5.4)	52.4 (4.5)	52.8 (5.9)
Behavior Rating Inventory of Executive Function												
Inhibit	50.9 (12.3)	50.4 (13.8)	50.4 (13.7)	47.9 (10.9)	47.8 (9.9)	49.7 (13.1)	48.9 (10.7)	51.5 (13.2)	52.7 (13.4)	49.0 (10.0)	46.8 (10.4)	46.6 (10.0)
Emotional control	48.4 (12.4)	50.4 (14.2)	49.6 (13.9)	47.3 (11.6)	50.5 (14.4)	50.2 (14.3)	45.9 (9.8)	51.3 (12.0)	52.0 (13.2)	48.0 (11.1)	44.7 (9.8)	45.0 (11.7)
Working memory	51.1 (11.5)	52.0 (13.9)	51.6 (13.2)	47.6 (10.6)	50.0 (12.1)	50.4 (12.9)	48.2 (11.7)	53.0 (12.1)	54.1 (13.4)	48.9 (10.4)	46.1 (10.2)	46.8 (12.0)
Plan/Organize	49.2 (11.6)	48.8 (13.0)	49.2 (12.7)	46.4 (10.4)	47.1 (11.2)	47.5 (13.2)	46.7 (10.9)	48.9 (12.0)	50.8 (13.3)	47.6 (10.3)	45.0 (10.7)	45.7 (11.5)
Metacognition Index ^b	49.9 (12.0)	49.3 (13.3)	49.3 (13.1)	46.9 (10.8)	48.2 (12.2)	49.0 (13.4)	46.1 (10.6)	49.8 (11.7)	50.4 (13.1)	47.6 (10.4)	43.9 (10.5)	45.3 (11.8)
Inhibitory Self-Control Index ^c	48.4 (11.7)	51.0 (17.4)	52.7 (17.4)	44.3 (9.9)	46.2 (13.5)	45.5 (13.9)	43.7 (8.4)	47.3 (10.4)	51.8 (16.1)	46.6 (10.1)	45.0 (13.1)	46.0 (14.6)
Emergent Metacognition Index ^c	48.7 (11.0)	49.4 (16.2)	52.4 (16.7)	44.3 (9.7)	44.6 (9.4)	44.5 (11.0)	44.6 (11.9)	48.6 (13.9)	53.2 (15.1)	46.7 (10.2)	46.5 (14.0)	48.0 (17.3)

^aStrengths and Difficulties Questionnaire measures are only applicable for children age 4 years and older.^bThe Metacognition Index is only applicable for children age 5 years and older.^cThe Inhibitory Self-Control Index and Emergent Metacognition Index are only applicable for children ages 2.5 to <5 years. ADHD, attention-deficit/hyperactivity disorder; SD, standard deviation; TBI, traumatic brain injury.

TABLE 3. STRENGTHS AND DIFFICULTIES QUESTIONNAIRE MULTIVARIABLE MODEL RESULTS

	<i>Emotional symptoms</i> (n = 389)		<i>Conduct problems</i> (n = 392)		<i>Hyperactivity</i> (n = 421)		<i>Peer problems</i> (n = 392)		<i>Prosocial</i> (n = 421)		<i>Total difficulties</i> (n = 389)	
	<i>coef</i> (SE)	<i>p</i>	<i>coef</i> (SE)	<i>p</i>	<i>coef</i> (SE)	<i>p</i>	<i>coef</i> (SE)	<i>p</i>	<i>coef</i> (SE)	<i>p</i>	<i>coef</i> (SE)	<i>p</i>
Pre-injury measure of outcome	0.43 (0.04)	<0.001	0.71 (0.04)	<0.001	0.68 (0.03)	<0.001	0.59 (0.04)	<0.001	0.61 (0.04)	<0.001	0.70 (0.04)	<0.001
injury severity		0.009		0.01		0.001		0.21		0.45		<0.001
Mild TBI	0.24 (0.35)		-0.02 (0.27)		0.39 (0.27)		-0.01 (0.16)		-0.16 (0.20)		0.64 (0.54)	
Complicated mild/moderate	-0.01 (0.33)		-0.13 (0.26)		0.98 (0.26)		0.05 (0.16)		-0.31 (0.20)		1.91 (0.53)	
Severe TBI	0.27 (0.39)		0.09 (0.30)		1.24 (0.30)		0.35 (0.19)		-0.25 (0.24)		2.41 (0.64)	
Orthopedic	Ref		Ref		Ref		Ref		Ref		Ref	
Time: 12 months vs. 3 months	-0.18 (0.11)	0.09	0.03 (0.08)	0.75	-0.09 (0.20)	0.01	0.12 (0.09)	0.20	0.03 (0.12)	0.78	-0.25 (0.25)	0.33
Injury severity by time	-	-	-	-	Figure 2A	0.01	-	-	-	-	-	-
Age group		0.12		0.05		0.02		-		-		0.03
4 to 5 years	-0.24 (0.40)		-0.29 (0.31)		0.25 (0.22)		-		-		0.61 (0.56)	
6 to 11 years	-0.07 (0.34)		-0.08 (0.26)		0.51 (0.18)		-		-		1.21 (0.44)	
12 to 15 years	Ref		Ref		Ref		-		-		Ref	
Age group by injury severity	Figure 2	0.02	Figure 2	0.04	-	-	-	-	-	-	-	-
Race/Ethnicity		<0.001		-		-		-		-		0.001
Hispanic or Latino	-0.75 (0.20)										-1.79 (0.51)	
Black, non-Hispanic	-0.37 (0.35)										-0.02 (0.88)	
Other, non-Hispanic	0.45 (0.32)										0.97 (0.81)	
White, non-Hispanic	Ref										Ref	
Spanish preferred language	-	-	-0.71 (0.21)	0.001	-	-	-0.51 (0.20)	0.01	-	-	-	-
Respondent education	-	-	-	-	-	-	-	-	-	-	-	-
Less than high school									0.55 (0.27)	0.009		
High school									Ref			
Vocational/Some college									-0.26 (0.21)			
Bachelor's degree or higher									-0.18 (0.22)			
Poverty level	-0.14 (0.04)	0.002	-0.08 (0.03)	0.02	-	-	-0.06 (0.03)	0.09	-	-	-0.29 (0.11)	0.01
Family function	-	-	-	-	-	-	0.30 (0.14)	0.03	-0.31 (0.17)	0.07	-	-
Social capital	-0.24 (0.08)	0.003	-0.15 (0.06)	0.02	-0.16 (0.08)	0.04	-0.15 (0.06)	0.02	0.24 (0.08)	0.002	-0.72 (0.21)	0.001
Max AIS excluding head	-	-	-	-	0.18 (0.08)	0.03	-	-	-	-	-	-

When an interaction is present, main effects must be interpreted in the presence of the interaction. See Figure 2.

- Indicates that this variable is not included in the final model for this outcome.

AIS, Abbreviated Injury Score; SE, standard error; TBI, traumatic brain injury.

score than children with OI, on average. For emotional symptoms and conduct problems, the effect of injury severity varied by age group (Fig. 2); ratings were elevated for pre-school and school-aged children with complicated mild/moderate and severe TBI relative to adolescents. School-aged children had higher hyperactivity scores. A severity by time interaction indicated that initially elevated hyperactivity scores decreased from 3 to 12 months in the severe and complicated mild/moderate TBI groups (Fig. 3A). Neither severity nor age were important in the scales measuring peer and prosocial interactions. Family environment was important in all SDQ models. High social capital, higher income, and better family functioning contributed to positive outcomes. Demographic variables had specific associations with SDQ scores: Hispanic ethnicity was associated with fewer emotional symptoms and total difficulties, Spanish language preference predicted fewer conduct and peer problems, and lower respondent education predicted positive prosocial outcomes.

Child Behavior Checklist. Injury type and severity, age, and child sex were important predictors of the three CBCL subscales (Table 4). Children of all TBI severities had higher scores on the affective, anxiety, and ADHD subscales compared with OI children. On the affective subscale, there was an interaction between age and injury severity with school-age children with complicated

mild/moderate and severe TBI reporting more problems than other groups (Fig. 2).

Injury severity interacted with time of assessment as shown in Figure 3A. Children with mild TBI had similar scores on the anxiety scale as children with severe injury 3 months post-injury, but symptom trajectories differed: children with mild and complicated mild/moderate injury had decreasing symptoms over time, whereas children with severe injury had increasing symptoms.

Children's symptom trajectories also differed dependent on age at injury. School-age children had the highest ADHD and affective symptoms scores, but pre-schoolers showed increases in symptoms over time in (Fig. 3B). Girls had significantly higher scores on all CBCL outcomes indicating more problems. Children with Hispanic ethnicity had fewer problems compared with white, non-Hispanic children on the affective disorder subscale. A positive family environment contributed to better outcomes on all CBCL scales.

Executive Function: BRIEF and BRIEF-P. Children with TBI performed more poorly on the BRIEF subscales compared with children with OI (Table 5). Higher TBI severity was typically associated with higher (worse) scores; however, children with mild or complicated mild/moderate TBI also had clinically important higher scores on working memory relative to children with OI.

FIG. 2. Illustration of interactions between age and injury severity. Predicted mean scores (± 1 standard error) assuming average values of pre-injury scores and other covariates.

FIG. 3. Illustration of interactions between time and injury severity (Fig. 3A) and time and age (Fig. 3B). Predicted mean scores ($\pm$ standard error) assuming average values of pre-injury scores and other covariates.

Pre-school children performed better on working memory relative to adolescents. Emotional control subscale scores were elevated for middle school children with complicated/mild to severe TBI and in younger children with mild TBI (Fig. 2). On the BRIEF-P, administered to 2 to 4 year olds, children with TBI had higher scores for both inhibitory self-control ($p=0.01$) and metacognition ($p=0.03$) compared with OI across all injury severities. On both BRIEF-P scales, children with mild TBI had clinically elevated scores similar to children with severe TBI. Social capital was a significant predictor of executive function ratings.

Discussion

To our knowledge, this is the first study to directly compare longitudinal psychosocial and executive function outcomes in a large sample of children with TBI or OI injured during pre-school, middle childhood, and adolescent stages of development. This large prospective cohort demonstrates that children have diverse psychosocial and executive function difficulties

following TBI compared with children with OI, and that these difficulties persist for at least 12 months. Peer relationships and prosocial behaviors were not significantly affected by TBI and were related to positive family functioning and social capital. As posited by the ICDFH, outcomes varied depending on the child's injury type and severity, personal characteristics, and family environment.

Similar to prior studies, younger age at injury was a risk factor for adverse outcomes in specific psychosocial and executive function domains. Pre-schoolers and school-age children were vulnerable to adverse effects of TBI in terms of reduced emotional control, elevated emotional and affective symptoms, and conduct problems. Consistent with study by Karver and colleagues, pre-schoolers showed increasing ADHD and affective problems during the first year after injury.²¹ This finding is particularly relevant given the importance of attention and emotional control for later self-regulation of behavior and academic success after TBI.^{22,23} Executive function and psychosocial difficulties likely contribute to the lower functional academic skills in younger children and

TABLE 4. CHILD BEHAVIOR CHECKLIST MULTIVARIABLE MODEL RESULTS

	ADHD (n = 506)		Affective disorder (n = 466)		Anxiety disorder (n = 483)	
	coef (SE)	p	coef (SE)	p	coef (SE)	p
Pre-injury measure of outcome	0.63 (0.03)	<0.001	0.43 (0.05)	<0.001	0.52 (0.04)	<0.001
Injury severity		<0.001		<0.001		<0.001
Mild TBI	2.05 (0.56)		0.71 (1.36)		2.72 (0.80)	
Complicated mild/Moderate	2.19 (0.54)		2.68 (1.30)		3.77 (0.79)	
Severe TBI	3.00 (0.64)		0.67 (1.55)		2.62 (0.94)	
Orthopedic	Ref		Ref		Ref	
Time: 12 months vs. 3 months	−0.78 (0.47)	0.85	−0.26 (0.62)	0.64	0.35 (0.62)	0.53
Injury severity by time	—	—	—	—	Figure 3A	0.04
Age group	Figure 3B	0.04	Figure 2 Figure 3B	0.03	—	—
Age group by injury severity	—	—	Figure 2	0.01	—	—
Age group by time	Figure 3B	0.03	Figure 3B	0.05	—	—
Female	1.17 (0.43)	0.007	1.08 (0.59)	0.07	1.15 (0.52)	0.03
Race/Ethnicity	—	—		0.02	—	—
Hispanic or Latino			−2.04 (0.71)			
Black, non-Hispanic			−1.22 (1.17)			
Other, non-Hispanic			1.10 (1.16)			
White, non-Hispanic			Ref			
Poverty level	—	—	−0.41 (0.16)	0.01	−0.30 (0.13)	0.02
Family function	0.78 (0.48)	0.10	1.76 (0.67)	0.01	1.63 (0.56)	0.004
Social capital	−0.40 (0.20)	0.05	−0.67 (0.30)	0.03	—	—

When an interaction is present, main effects must be interpreted in the presence of the interaction. See Figure 2 and Figure 3.

— Indicates that this variable is not included in the final model for this outcome.

ADHD, attention-deficit/hyperactivity disorder; SE, standard error, TBI, traumatic brain injury.

emergence of increased academic difficulty years after complicated mild/moderate TBI.²⁴

Time since injury also influenced the trajectory of several outcomes across the first year after TBI. For example, children with severe TBI had improvements in their hyperactivity ratings but increasing anxiety scores from the 3- to 12-month time-points. Children with less severe TBI showed decreasing anxiety over time. Executive function ratings, however, remained relatively stable across the first year after TBI in school-age children and adolescents similar to other studies showing limited change in executive functions during the first 2 years after TBI.^{7,25} Our findings that executive functions in pre-schoolers changed over time, shown by increasing difficulty in BRIEF-P indices, suggest that children have different symptom trajectories depending on their developmental stage when injured, the outcome under investigation, as well as their injury severity.^{2,3,26}

Characteristics of the child and family affected multiple outcomes. Adjusted for pre-injury scores, girls performed worse than boys on all CBCL behavioral scales. Although sex differences in the development of psychiatric symptoms after TBI have been suggested in the past, the ability to detect differences was limited by sample size.²⁷ These data suggest that girls may need more psychological support than boys following TBI. The sex findings on the CBCL are not reflected on the SDQ emotional or attention scales. The CBCL uses both age and sex in the scoring, whereas the SDQ reports raw scores, which may obscure sex differences. Hispanic ethnicity and/or Spanish-language preference was a protective factor associated with fewer emotional symptoms and peer problems as well as better conduct. Hispanic families may have cultural features that promote resilience to chronic illness even in the face of socioeconomic challenges.²⁸

Consistent with the literature, family environment was important to all outcomes.^{6,19,25} Families with higher social and financial resources may have more capacity to make and keep medical appointments after TBI and may experience less stress. However, more nuanced differences between high and low resource families may exist. Parent psychological functioning and communication skills are known to affect externalizing behaviors among adolescents post-TBI.²⁹ The home environment and parenting style have long-term impacts on functional outcomes of children recovering from TBI.³⁰ The current results reflect that high social capital in addition to more traditional measures of family environment is important to outcomes. Social capital may provide an additional target for intervention to improve health outcomes for children with TBI.

This study's results should be interpreted in view of its limitations. We used parent-reported outcomes: parents may inaccurately report their child's symptoms, especially in the adolescent population. We used well-validated measures of executive function and psychosocial outcomes; however, these may differ from in-person assessments. We chose to include Spanish-language speakers to increase the study's generalizability; however, these parents were interviewed by telephone and not offered the option of web assessments. Prior studies have found web and phone assessments of children with TBI are similar.³¹

Conclusion

Children with TBI have differing trajectories of recovery and development of new problems dependent on their injury severity and developmental stage at injury. Pediatricians and schools need to re-evaluate children's skills over time as new problems in behavior and learning may emerge. Ongoing surveillance is especially important for children injured at a young age. Younger age at injury was associated with poorer outcomes in several areas

TABLE 5. BEHAVIOR RATING INVENTORY OF EXECUTIVE FUNCTION MULTIVARIABLE MODEL RESULTS

	Inhibit (n=468)			Emotional control (n=468)			Working memory (n=468)			Plan/Organize (n=502)			Metacognition Index (5+ years, n=372)			Emergent Metacognition (<5 years, n=130)			Inhibitory Self-Control Index (<5 years, n=130)		
	coef (SE)	p		coef (SE)	p		coef (SE)	p		coef (SE)	p		coef (SE)	p		coef (SE)	p		coef (SE)	p	
Pre-injury measure of outcome	0.69 (0.04)	<0.001		0.64 (0.04)	<0.001		0.66 (0.04)	<0.001		0.62 (0.04)	<0.001		0.72 (0.04)	<0.001		0.73 (0.09)	<0.001		0.68 (0.11)	<0.001	
Injury severity		<0.001			<0.001			<0.001			0.001			<0.001			0.14			0.05	
Mild TBI	3.92 (1.16)			0.82 (2.12)			5.28 (1.21)			2.56 (1.03)			2.40 (1.16)			6.26 (2.97)			9.61 (3.45)		
Complicated mild/ Moderate TBI	4.04 (1.15)			2.91 (2.04)			6.42 (1.20)			2.75 (1.01)			4.40 (1.13)			4.03 (2.94)			7.35 (3.40)		
Severe TBI	5.78 (1.26)			4.79 (2.39)			8.05 (1.32)			4.57 (1.20)			6.08 (1.30)			6.13 (3.29)			6.15 (3.80)		
Orthopedic	Ref			Ref			Ref			Ref			Ref			Ref			Ref		
Time: 12 vs. 3 months	0.49 (0.42)	0.25		-0.21 (0.49)	0.66		0.06 (0.47)	0.90		0.68 (0.47)	0.15		0.67 (0.47)	0.16		2.35 (1.23)	0.06		1.92 (1.02)	0.06	
Injury severity by time																					
Age group																					
2.5 to 5 years	-	-		-	-		-	-		-	-		-	-		-	-		-	-	
6 to 11 years	-	-		-2.43 (2.14)	0.12		-2.19 (1.04)	0.04		-	-		-	-		-	-		-	-	
12 to 15 years				-1.89 (2.08)			0.14 (0.99)														
Age group by injury severity				Ref			Ref														
Spanish language	-	-		Figure 2	0.005		-	-		-	-		-	-		-	-		-	-	
Respondent education																					
Less than high school				-3.61 (1.45)	0.01		-	-		-	-		-	-		-	-		-	-	
High school	3.61 (1.42)	0.01																			
Vocational/Some college	Ref																				
Bachelor's degree or higher	3.16 (1.09)																				
Poverty level	3.13 (1.25)																				
Family function	-0.46 (0.24)	0.06		-0.54 (0.25)	0.03		-0.47 (0.23)	0.04		-	-		-	-		-	-		-	-	
Social capital	1.51 (0.91)	0.10		-	-		-	-		2.51 (0.88)	0.005		2.59 (0.99)	0.009		-	-		-	-	
Max AIS excluding head	-0.85 (0.41)	0.04		-1.01 (0.46)	0.03		-1.35 (0.42)	0.002		-1.41 (0.38)	<0.001		-1.20 (0.42)	0.005		-2.11 (1.03)	0.04		-3.13 (1.20)	0.01	
	0.93 (0.41)	0.02		-	-		0.94 (0.43)	0.03		-	-		-	-		2.01 (1.05)	0.06		2.59 (1.22)	0.04	

When an interaction is present, main effects must be interpreted in the presence of the interaction. See Figure 2.

- Indicates that this variable is not included in the final model for this outcome.

AIS, Abbreviated Injury Score; SE: standard error; TBI, traumatic brain injury.

encompassing emotional functioning, behavior regulation, and metacognition indices, which all contribute to later school success.

Acknowledgment

This study was supported by The Centers for Disease Control under Cooperative Agreement U01/CE002188. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention. This study was supported also by the National Institute of Health/Eunice Kennedy Shriver National Institute of Child Health and Human Development K24HD072984. Neither the NICHD or the CDC played a role in the design or conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Author Disclosure Statement

No competing financial interests exist.

References

- Giza, C.C., Kolb, B., Harris, N.G., Asarnow, R.F., and Prins, M.L. (2009). Hitting a moving target: basic mechanisms of recovery from acquired developmental brain injury. *Dev. Neurorehabil.* 12, 255–268.
- Yeates, K.O., Bigler, E.D., Dennis, M., Gerhardt, C.A., Rubin, K.H., Stancin, T., Taylor, H.G., and Vannatta, K. (2007). Social outcomes in childhood brain disorder: a heuristic integration of social neuroscience and developmental psychology. *Psychol. Bull.* 133, 535–556.
- Ewing-Cobbs, L., Barnes, M., Fletcher, J.M., Levin, H.S., Swank, P.R., and Song, J. (2004). Modeling of longitudinal academic achievement scores after pediatric traumatic brain injury. *Dev. Neuropsychol.* 25, 107–133.
- Ryan, N.P., van Bijn, L., Catroppa, C., Beauchamp, M.H., Crossley, L., Hearn, S., and Anderson, V. (2016). Longitudinal outcome and recovery of social problems after pediatric traumatic brain injury (TBI): contribution of brain insult and family environment. *Int. J. Dev. Neurosci.* 49, 23–30.
- Pierce, C.A., and Hanks, R.A. (2006). Life satisfaction after traumatic brain injury and the World Health Organization model of disability. *Am. J. Phys. Med. Rehabil.* 85, 889–898.
- Yeates, K.O., Swift, E., Taylor, H.G., Wade, S.L., Drotar, D., Stancin, T., and Minich, N. (2004). Short- and long-term social outcomes following pediatric traumatic brain injury. *J. Int. Neuropsychol. Soc.* 10, 412–426.
- Kurowski, B.G., Taylor, H.G., Yeates, K.O., Walz, N.C., Stancin, T., and Wade, S.L. (2011). Caregiver ratings of long-term executive dysfunction and attention problems after early childhood traumatic brain injury: family functioning is important. *PM&R* 3, 836–845.
- Marr, A.L., and Coronado, V.G. (2004). *Central Nervous System Injury Surveillance Data Submission Standards: 2002*. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control: Atlanta, GA.
- Teasdale, G., and Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *Lancet* 2, 81–84.
- Carroll, L.J., Cassidy, J.D., Holm, L., Kraus, J., and Coronado, V.G. (2004). Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J. Rehabil. Med.* 43, 113–125.
- National Center for Injury Prevention and Control. (2003). *Report to Congress on Mild Traumatic Brain Injury in the US: Steps to Prevent a Serious Public Health Problem*. Centers for Disease Control and Prevention: Atlanta, GA.
- Gennarelli, T.A., and Wodzin, E. (2008). *Abbreviated Injury Scale 2005*. Association for the Advancement of Automotive Medicine: Des Plaines, IL.
- McCauley, S.R., Wilde, E.A., Anderson, V.A., Bedell, G., Beers, S.R., Campbell, T.F., Chapman, S.B., Ewing-Cobbs, L., Gerring, J.P., Gioia, G.A., Levin, H.S., Michaud, L.J., Prasad, M.R., Swaine, B.R., Turkstra, L.S., Wade, S.L., and Yeates, K.O. (2012). Recommendations for the use of common outcome measures in pediatric traumatic brain injury research. *J. Neurotrauma* 29, 678–705.
- Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. *J. Child Psychol. Psychiatry* 38, 581–586.
- Stone, L.L., Otten, R., Engels, R.C., Vermulst, A.A., and Janssens, J.M. (2010). Psychometric properties of the parent and teacher versions of the strengths and difficulties questionnaire for 4- to 12-year-olds: a review. *Clin. Child Fam. Psychol. Rev.* 13, 254–274.
- Achenbach, T.M., and Ruffle, T.M. (2000). The Child Behavior Checklist and related forms for assessing behavioral/emotional problems and competencies. *Pediatr. Rev.* 21, 265–271.
- Gioia, G.A., Isquith, P.K., Guy, S.C., and Kenworthy, L. (2000). *Behavior Rating Inventory of Executive Function*. Psychological Assessment Resources: Odessa, FL.
- Miller, I.W., Bishop, D.S., Epstein, N.B., and Kietner, G.I. (1985). The McMaster family assessment device: reliability and validity. *J. Marital Fam. Ther.* 11, 345–356.
- Runyan, D.K., Hunter, W.M., Socolar, R.R., Amaya-Jackson, L., English, D., Landsverk, J., Dubowitz, H., Browne, D.H., Bangdiwala, S.I., and Mathew, R.M. (1998). Children who prosper in unfavorable environments: the relationship to social capital. *Pediatrics* 101, 12–18.
- Levin, H.S., Hanten, G., Roberson, G., Li, X., Ewing-Cobbs, L., Dennis, M., Chapman, S., Max, J.E., Hunter, J., Schachar, R., Luerssen, T.G., and Swank, P. Prediction of cognitive sequelae based on abnormal computed tomography findings in children following mild traumatic brain injury. *J. Neurosurg. Pediatr.* 2008, 461–470.
- Karver, C.L., Wade, S.L., Cassidy, A., Taylor, H.G., Stancin, T., Yeates, K.O., and Walz, N.C. (2012). Age at injury and long-term behavior problems after traumatic brain injury in young children. *Rehabil. Psychol.* 57, 256–265.
- Arnett, A.B., Peterson, R.L., Kirkwood, M.W., Taylor, H.G., Stancin, T., Brown, T.M., and Wade, S.L. (2013). Behavioral and cognitive predictors of educational outcomes in pediatric traumatic brain injury. *J. Int. Neuropsychol. Soc.* 19, 881–889.
- Ganesalingam, K., Sanson, A., Anderson, V., and Yeates, K.O. (2007). Self-regulation as a mediator of the effects of childhood traumatic brain injury on social and behavioral functioning. *J. Int. Neuropsychol. Soc.* 13, 298–311.
- Prasad, M.R., Swank, P.R., and Ewing-Cobbs, L. (2017). Long-term school outcomes of children and adolescents with traumatic brain injury. *J. Head Trauma Rehabil.* 32, e24–e32.
- Sesma, H.W., Slomine, B.S., Ding, R., and McCarthy, M.L. Children's Health After Trauma (CHAT) Study Group. (2008). Executive functioning in the first year after pediatric traumatic brain injury. *Pediatrics* 121, e1686–e1695.
- Dennis, M., Spiegler, B.J., Simic, N., Sinopoli, K.J., Wilkinson, A., Yeates, K.O., Taylor, H.G., Bigler, E.D., and Fletcher, J.M. (2014). Functional plasticity in childhood brain disorders: when, what, how, and whom to assess. *Neuropsychol. Rev.* 24, 389–408.
- Max, J.E., Wilde, E.A., Bigler, E.D., MacLeod, M., Vasquez, A.C., Schmidt, A.T., Chapman, S.B., Hotz, G., Yang, T.T., and Levin, H.S. (2012). Psychiatric disorders after pediatric traumatic brain injury: a prospective, longitudinal, controlled study. *J. Neuropsychiatry Clin. Neurosci.* 24, 427–436.
- Gallo, L.C., Penedo, F.J., Espinosa de los Monteros, K., and Arguelles, W. (2009). Resiliency in the face of disadvantage: do Hispanic cultural characteristics protect health outcomes? *J. Pers.* 77, 1707–1746.
- Raj, S.P., Wade, S.L., Cassidy, A., Taylor, H.G., Stancin, T., Brown, T.M., and Kirkwood, M.W. (2014). Parent psychological functioning and communication predict externalizing behavior problems after pediatric traumatic brain injury. *J. Pediatr. Psychol.* 39, 84–95.
- Wade, S.L., Zhang, N., Yeates, K.O., Stancin, T., and Taylor, H.G. (2016). Social environmental moderators of long-term functional outcomes of early childhood brain injury. *JAMA. Pediatr.* 170, 343–349.
- Rivara, F.P., Koepsell, T.D., Wang, J., Durbin, D., Jaffe, K.M., Vavilala, M., Dorsch, A., Roper-Caldbeck, M., Houseknecht, E., and Temkin, N. (2011). Comparison of telephone with World Wide Web-based responses by parents and teens to a follow-up survey after injury. *Health Serv. Res.* 46, 964–981.

Address correspondence to:
Heather T. Keenan, MDCM, PhD
Department of Pediatrics
University of Utah
295 Chipeta Way, PO Box 581289
Salt Lake City, UT 84158

E-mail: heather.keenan@hsc.utah.edu