

Reliable Change in Postconcussive Symptoms and Its Functional Consequences Among Children With Mild Traumatic Brain Injury

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Objective: To examine reliable change in postconcussive symptoms and its functional consequences among children with mild traumatic brain injury (TBI) over the first year postinjury as compared with children with orthopedic injuries.

Design: Prospective, longitudinal cohort.

Setting: Emergency departments at 2 children's hospitals.

Participants: Eight- to 15-year-old children with mild TBI (n=186) or orthopedic injuries (n=99).

Main Exposure: Closed-head or orthopedic trauma.

Main Outcome Measures: Parents rated preinjury symptoms retrospectively shortly after injury and postconcussive symptoms at 2 weeks and 3 and 12 months postinjury. A regression-based approach was used to determine whether each child displayed reliable increases in postconcussive symptoms at each postinjury occasion. Health-related quality of life was assessed at 3 and 12 months postinjury. Information regarding children's

educational programming was collected at the initial and 12-month assessments.

Results: Children with mild TBI were significantly more likely than those with orthopedic injuries to show reliable increases in both cognitive and somatic symptoms. Group differences in the likelihood of reliable increases became less common with time for somatic symptoms but persisted to 12 months postinjury for cognitive symptoms. Among children with mild TBI, reliable increases in symptoms were more common among children with loss of consciousness or abnormalities on neuroimaging. Reliable increases in symptoms were associated with significant declines in health-related quality of life and an increased likelihood of educational intervention.

Conclusion: Many children with mild TBI show reliable increases in postconcussive symptoms that are associated with significant functional impairment in their daily lives.

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MILD TRAUMATIC BRAIN injuries (TBIs) are common in children and adolescents. Annually in the United States, more than 500 000 youth younger than 15 years sustain TBIs that require hospital-based medical care, most of which are mild in severity.^{1,2} Even if only a small proportion of children with mild TBI have persistent negative outcomes, then mild TBI is a serious public health problem.^{3,4}

*For editorial comment
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Although some reviews suggest that mild TBI has little effect on children,^{5,6} a growing literature indicates that children with mild TBI display more postconcus-

sive symptoms than children with injuries not involving the head or healthy children.⁷⁻¹³ Postconcussive symptoms include somatic (eg, headache and fatigue) and cognitive (eg, inattention, forgetfulness, and slowing) complaints commonly reported after mild TBI, albeit not specific to that condition.

Group differences in postconcussive symptoms are most pronounced shortly after injury.^{7,10,11} Group differences also are larger following complicated mild TBI, as defined by abnormalities on neuroimaging, than after uncomplicated mild TBI.^{11,14} Other indicators of severity, such as loss of consciousness (LOC), are also related to persistent postconcussive symptoms.^{7,11,13} Group differences in postconcussive symptoms also vary as a function of noninjury factors.^{14,15}

Comparisons of group means are informative but do not indicate whether in-

Table 1. Demographic and Clinical Characteristics of Participants

Variable	OI	Mild TBI
Sample size	99	186
Age at injury, y, mean (SD)	11.76 (2.23)	11.96 (2.22)
Male, No. (%)	64 (65)	132 (71)
White, No. (%)	64 (65)	132 (71)
Socioeconomic status, mean (SD)	-0.09 (1.15)	0.05 (0.91)
Full-scale IQ at initial assessment, mean (SD)	98.90 (15.09)	99.66 (13.83)
Modified Injury Severity Scale score, mean (SD)	3.25 (1.52)	4.62 (4.54)
Loss of consciousness, No. (%)	NA	74 (40)
Abnormal MRI	NA	32 (18)

Abbreviations: MRI, magnetic resonance imaging; NA, not applicable; OI, orthopedic injuries; TBI, traumatic brain injury.

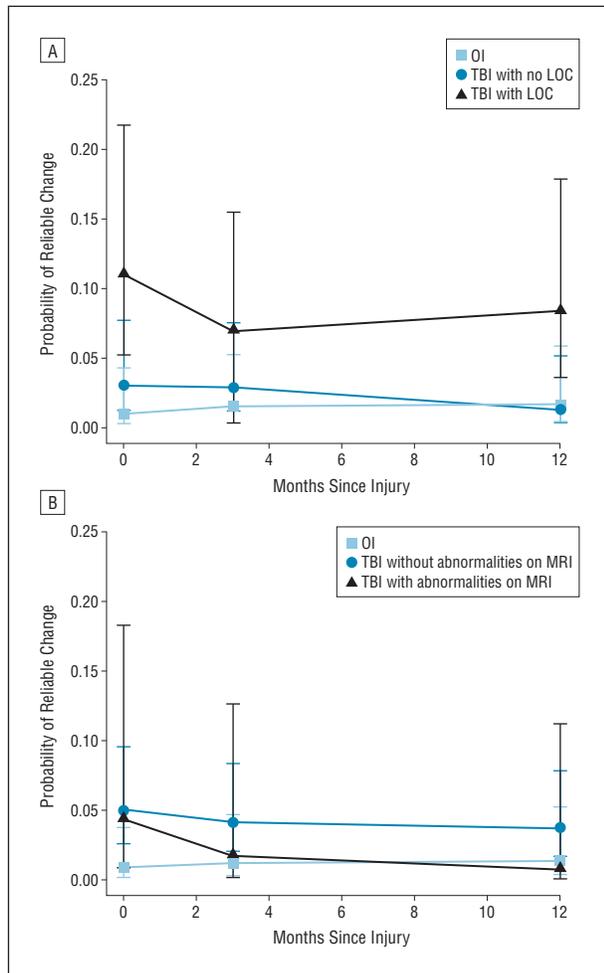


Figure 1. Probability of reliable change in cognitive symptoms as a function of group membership. Children with mild traumatic brain injury (TBI) are divided into those with and without loss of consciousness (LOC) (A) and with and without abnormalities on magnetic resonance imaging (MRI) (B). OI indicates orthopedic injuries.

dividual children show significant increases in postconcussive symptoms following mild TBI more commonly than after other injuries. Analyses of reliable change have become a common approach to assessing individual changes in neurobehavioral functioning, including recovery from mild TBI.^{16,17} Analyses of reliable change determine whether an individual displays a statistically reliable change in scores across 2 occasions.

Regression-based methods generally yield the most accurate estimates of reliable change.^{17,18} In this approach, follow-up scores are regressed on baseline scores in a normative sample to generate a formula for predicting follow-up scores.¹⁹ A standardized change score is computed by subtracting the predicted score from the actual follow-up score and dividing by the standard error of the estimate. If the standardized change score exceeds a predetermined value, it is considered to reflect reliable change.

We used data from a prospective, longitudinal project²⁰ to examine reliable change in postconcussive symptoms among children with mild TBI as compared with children with orthopedic injuries (OI). We have previously shown that children with mild TBI on average display more symptoms than children with OI^{11,13} but have not examined individual change through analyses of reliable change; moreover, to our knowledge, no previous study has done so. We expected children with mild TBI to demonstrate reliable increases in postconcussive symptoms more often than children with OI, especially after more severe injuries, as indexed by LOC or abnormalities on magnetic resonance imaging (MRI).

We also sought to determine whether reliable change in postconcussive symptoms following mild TBI predicts significant functional impairment. In adults, persistent postconcussive symptoms are associated with occupational disability.²¹ Moreover, in children with moderate to severe TBI, neurobehavioral symptoms predict poorer adaptive functioning and academic performance.²² However, the functional significance of postconcussive symptoms in children with mild TBI remains uncertain. We expected that reliable increases in postconcussive symptoms among children with mild TBI would predict declines in health-related quality of life (HRQOL) and increases in educational intervention.

METHODS

PARTICIPANTS

Participants were children between 8 and 15 years of age presenting with either closed-head trauma or OI at the emergency departments at Nationwide Children's Hospital in Columbus, Ohio, and Rainbow Babies and Children's Hospital in Cleveland, Ohio. Children in the mild TBI group demonstrated an observed LOC; a lowest Glasgow Coma Scale²³ score of 13 or 14; or

Table 2. Coefficients for Longitudinal Models of Reliable Change

Independent Variable	Mild TBI Subgroups, Coefficient (95% CI)			
	LOC vs No LOC		Abnormal MRI vs Normal MRI	
	Cognitive Symptoms	Somatic Symptoms	Cognitive Symptoms	Somatic Symptoms
Intercept	-6.27	-7.14	-6.66	-7.13
Age at injury	-0.14 (-0.35 to 0.05)	-0.02 (-0.15 to 0.11)	-0.13 (-0.33 to 0.07)	-0.02 (-0.15 to 0.11)
Socioeconomic status	0.07 (-0.37 to 0.51)	-0.02 (-0.32 to 0.32)	0.11 (-0.35 to 0.58)	0.02 (-0.30 to 0.34)
Total CBCL T score	-0.003 (-0.07 to 0.04)	0.04 (0.01 to 0.07)	-0.004 (-0.05 to 0.04)	0.04 (0.01 to 0.07)
FAD-GF total score	0.47 (-0.60 to 1.54)	-0.16 (-0.91 to 0.60)	0.50 (-0.65 to 1.66)	-0.11 (-0.88 to 0.65)
BSI-GSI T score	0.06 (0.01 to 0.10) ^a	0.05 (0.02 to 0.08) ^a	0.06 (0.01 to 0.10) ^a	0.05 (0.02 to 0.08) ^a
Time: 3 mo postinjury (baseline = at injury)	0.34 (-1.39 to 2.07)	-0.11 (-1.45 to 1.23)	0.35 (-1.41 to 2.11)	-0.11 (-1.45 to 1.23)
Time: 12 mo postinjury (baseline = at injury)	0.44 (-1.30 to 2.18)	-0.26 (-1.67 to 1.16)	0.46 (-1.32 to 2.23)	-0.26 (-1.67 to 1.15)
No LOC (baseline = OI)	1.13 (-0.57 to 2.84)	2.05 (0.94 to 3.16) ^a		
LOC (baseline = OI)	2.46 (0.81 to 4.11) ^a	2.79 (1.64 to 3.94) ^a		
No LOC × 3 mo postinjury	-0.41 (-2.52 to 1.70)	-1.05 (-2.62 to 0.52)		
No LOC × 12 mo postinjury	-1.33 (-3.65 to 1.00)	-2.268 (-4.16 to -0.38)		
LOC × 3 mo postinjury	-0.84 (-2.85 to 1.17)	-1.91 (-3.58 to -0.24)		
LOC × 12 mo postinjury	-0.75 (-2.76 to 1.26)	-1.85 (-3.61 to -0.10) ^a		
Normal MRI (baseline = OI)			1.80 (0.16 to 3.44) ^a	2.19 (1.12 to 3.27) ^a
Abnormal MRI (baseline = OI)			1.66 (-0.51 to 3.82)	3.01 (1.71 to 4.32) ^a
Normal MRI × 3 mo postinjury			-0.54 (-2.49 to 1.41)	-1.44 (-2.96 to 0.09)
Normal MRI × 12 mo postinjury			-0.77 (-2.75 to 1.21)	-1.84 (-3.50 to -0.18)
Abnormal MRI × 3 mo postinjury			-1.27 (-4.14 to 1.60)	-1.36 (-3.20 to 0.48)
Abnormal MRI × 12 mo postinjury			-2.21 (-5.60 to 1.19)	-2.65 (-4.96 to -0.33) ^a

Abbreviations: BSI-GSI, Brief Symptom Inventory General Severity Index; CBCL, Child Behavior Checklist; FAD-GF, Family Assessment Device general functioning subscale; LOC, loss of consciousness; MRI, magnetic resonance imaging; OI, orthopedic injuries; TBI, traumatic brain injury.
^a*P* < .05.

at least 2 signs/symptoms of concussion as documented by emergency department personnel. Children were not excluded for intracranial lesions or skull fractures or if they were hospitalized; however, they were excluded for any Glasgow Coma Scale score less than 13 or any medical contraindication to MRI.

Children in the OI group sustained an upper or lower extremity fracture yielding a score of 1 to 3 on the Abbreviated Injury Scale.²⁴ Children were excluded from the OI group for any evidence of head trauma or symptoms of concussion.

Exclusion criteria for both groups included any surgical intervention; any associated injury resulting in an Abbreviated Injury Scale score greater than 3 or that interfered with neuropsychological testing; hypoxia, hypotension, or shock following the injury; alcohol or drug ingestion associated with the injury; history of previous TBI requiring medical treatment; premorbid neurological disorder or mental retardation; history of severe psychiatric disorder; or assault or child abuse as the cause of injury.

The participation rate was 48% among children with mild TBI and 35% among those with OI. Participants and nonparticipants did not differ significantly in age, sex, minority status, or census tract measures of socioeconomic status (SES).

The final sample included 186 children with mild TBI and 99 children with OI. Of those, 268 (94%) completed the 3-month assessment and 253 (89%) completed the 12-month assessment. The proportion of completed assessments did not differ by group. Children who completed all assessments did not differ from those who did not do so in age, sex, preinjury symptoms, or early postinjury postconcussive symptoms but were more likely to be white and of higher SES.

The mild TBI and OI groups did not differ on age, sex, minority status, SES, or IQ (Table 1). The composite measure of SES was based on years of maternal education, median census tract family income, and the Duncan Socioeconomic Index, which measures occupational prestige²⁵; higher scores reflect higher SES. The mild TBI group had higher scores on the Modified Injury Severity Scale.²⁶

PROCEDURE

Institutional review board approval and parental consent and child assent were obtained prior to participation. Initial assessments occurred no later than 3 weeks postinjury (mean [SD], 11.35 [3.42] days). Parents rated children's preinjury symptoms and preinjury HRQOL retrospectively at the initial assessment. All but 4 children with mild TBI also completed MRI at that time. Parents provided ratings of postinjury symptoms at the initial assessment and at 3 and 12 months postinjury. Postinjury ratings of HRQOL were also collected at 3 and 12 months. Information was collected about preinjury educational intervention at the initial assessment and about postinjury educational intervention at 12 months.

MEASURES

Postconcussive Symptoms

Parents rated postconcussive symptoms using the Health and Behavior Inventory,²⁷ which is recommended as a core measure in the Eunice Kennedy Shriver National Institute of Child Health and Human Development Common Data Elements for TBI.²⁸ Scales representing cognitive and somatic symptoms were used as dependent variables.²⁷ Both scales demonstrated high internal consistency across assessment occasions (Cronbach α from .83-.95). We have previously demonstrated group mean differences on the Health and Behavior Inventory in the current sample.^{11,14}

Quality of Life

Parent ratings of children's HRQOL were obtained using the 50-item Child Health Questionnaire.²⁹ The Child Health Questionnaire yields standardized summary scores (mean [SD] = 50 [10]) for physical and psychosocial functioning. The reliability and va-

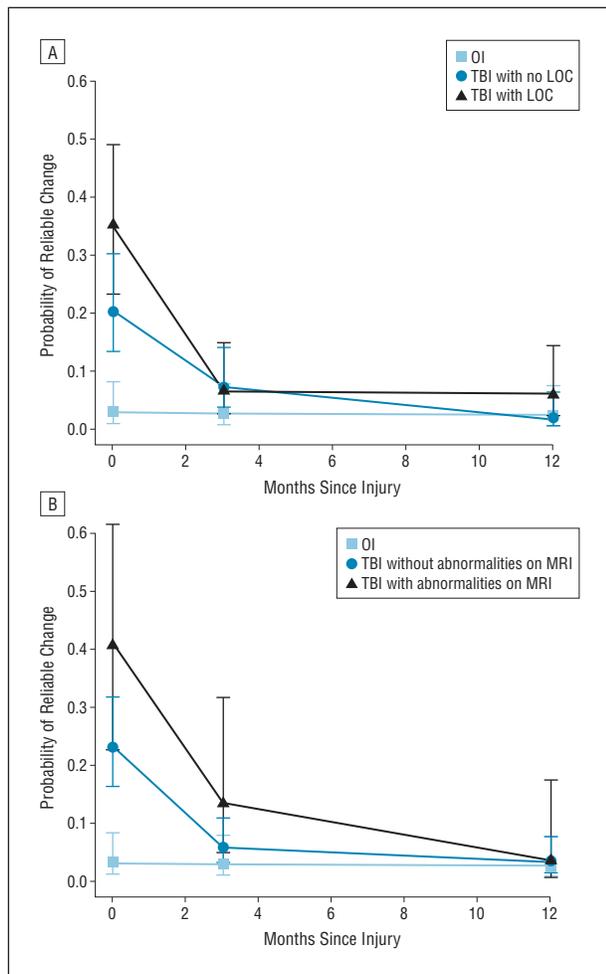


Figure 2. Probability of reliable change in somatic symptoms as a function of group membership. Children with mild traumatic brain injury (TBI) are divided into those with and without loss of consciousness (LOC) (A) and with and without abnormalities on magnetic resonance imaging (MRI) (B). OI indicates orthopedic injuries.

lidity of the Child Health Questionnaire have been established across a range of chronic health conditions,^{30,31} as well as in studies of children with TBI.^{32,33} Higher scores indicate better HRQOL.

Educational Intervention

Information regarding educational programming was obtained from parents and teachers via questionnaires and through requests for school records and individual education plans. Consistent with previous research,^{34,35} children were considered to be receiving educational intervention if they were provided with any special accommodations within the regular classroom, received tutorial or remedial services not part of special education, or had a formal special education placement.

Potential Confounders

Parents completed the Child Behavior Checklist,³⁶ Brief Symptom Inventory,^{37,38} and general functioning subscale from the Family Assessment Device³⁹⁻⁴¹ at the initial assessment to rule out potential confounders. The Child Behavior Checklist and the Family Assessment Device general functioning subscale were completed retrospectively to reflect premorbid child behavioral adjustment and family functioning. The Brief Symptom Inventory was completed to assess current parent psychological distress.

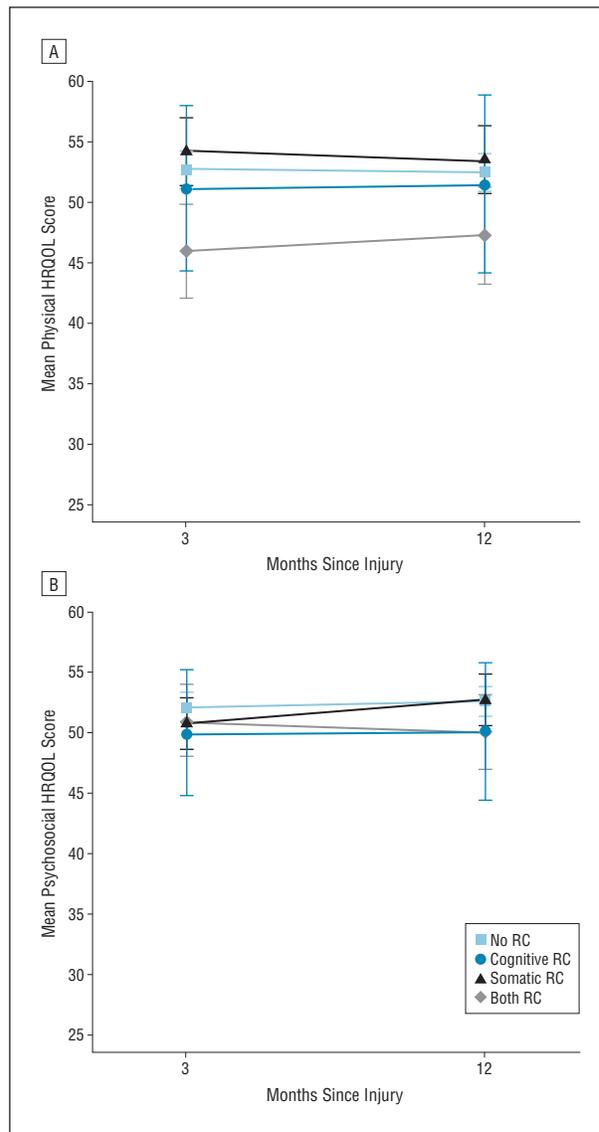


Figure 3. Mean ratings of physical health-related quality of life (HRQOL) (A) and psychosocial HRQOL (B) as a function of acute reliable change (RC) among children with mild traumatic brain injury.

DATA ANALYSES

To determine reliable change,¹⁹ postinjury ratings of postconcussive symptoms were regressed on ratings of preinjury symptoms in the OI sample, separately for each postinjury assessment occasion and for the Health and Behavior Inventory Cognitive and Somatic Symptom Scales. The resulting regression coefficients were used to compute standardized change scores for children in both the OI and TBI groups by subtracting predicted scores from the actual postinjury scores and dividing by the standard error of the estimate. Standardized scores exceeding 1.64 (ie, in the extreme 5% of the distribution) were considered to reflect a reliable increase in symptoms.

Mixed-models logistic regression was used to examine group differences in the probability of reliable increases in cognitive and somatic symptoms across the 3 postinjury assessments. The OI group was compared with the mild TBI group, which was divided into those with and without LOC or those with and without trauma-related abnormalities on MRI. In addition to dummy variables for group, predictors

Table 3. Coefficients for Longitudinal Models of HRQOL

Independent Variable	Time Postinjury When RC Assessed, Coefficient (95% CI)			
	Acutely		3 mo	
	Physical HRQOL	Psychosocial HRQOL	Physical HRQOL	Psychosocial HRQOL
Intercept	71.34	58.36	72.13	58.46
Age at injury	-0.42 (-0.92 to 0.08)	0.446 (0.08 to 0.82) ^a	-0.503 (-1.00 to -0.002) ^a	0.372 (0.02 to 0.72) ^a
Socioeconomic status	-0.06 (-1.27 to 1.181)	0.31 (-0.60 to 1.22)	-0.06 (-1.28 to 1.17)	0.34 (-0.52 to 1.19)
Total CBCL T score	-0.20 (-0.40 to -0.03) ^a	-0.11 (-0.23 to 0.01)	-0.19 (-0.36 to -0.03) ^a	-0.12 (-0.235 to -0.001) ^a
FAD-GF total score	2.24 (-0.64 to 5.12)	-0.33 (-2.46 to 1.80)	2.63 (-0.25 to 5.52)	0.18 (-1.84 to 2.19)
BSI-GSI T score	-0.15 (-0.29 to -0.03) ^a	-0.11 (-0.20 to -0.02) ^a	-0.15 (-0.28 to -0.03) ^a	-0.10 (-0.19 to -0.02) ^a
Preinjury physical HRQOL	0.19 (0.02 to 0.35) ^a	-0.11 (-0.23 to 0.01)	0.16 (-0.004 to 0.33)	-0.13 (-0.24 to -0.01) ^a
Preinjury psychosocial HRQOL	-0.15 (-0.34 to 0.04)	0.44 (0.30 to 0.58) ^a	-0.17 (-0.35 to 0.02)	0.43 (0.30 to 0.56) ^a
Time: 12 mo postinjury (baseline = 3 mo postinjury)	-0.26 (-1.20 to 1.48)	0.47 (-0.96 to 1.90)	-0.91 (-2.42 to 0.60)	0.57 (-0.70 to 1.84)
Cognitive RC (acute)	-1.53 (-8.54 to 5.48)	-2.18 (-7.55 to 3.19)		
Somatic RC (acute)	1.45 (-1.77 to 4.67)	-1.33 (-3.80 to 1.13)		
Both RC (acute)	-6.72 (-10.94 to -2.50) ^a	-1.10 (-4.33 to 2.12) ^a		
Cognitive RC (acute) × 12 mo	0.58 (-7.53 to 8.70)	-0.28 (-6.96 to 6.39) ^a		
Somatic RC (acute) × 12 mo	-0.40 (-3.92 to 3.13) ^a	1.51 (-1.39 to 4.42)		
Both RC (acute) × 12 mo	1.59 (-3.00 to 6.18)	-1.44 (-5.22 to 2.35)		
Cognitive RC (3 mo)			-3.22 (-8.00 to 1.56)	-6.27 (-9.82 to -2.72) ^a
Somatic RC (3 mo)			-2.24 (-6.88 to 2.39)	0.48 (-2.94 to 3.90)
Both RC (3 mo)			-17.43 (-24.49 to -10.37) ^a	-6.81 (-12.02 to -1.59) ^a
Cognitive RC (3 mo) × 12 mo			1.59 (-3.92 to 7.10)	-2.09 (-6.66 to 2.48)
Somatic RC (3 mo) × 12 mo			2.55 (-2.25 to 7.34)	-0.93 (-4.96 to 3.09)
Both RC (3 mo) × 12 mo			12.27 (4.42 to 20.11) ^a	6.97 (0.42 to 13.51) ^a

Abbreviations: BSI-GSI, Brief Symptom Inventory General Severity Index; CBCL, Child Behavior Checklist; FAD-GF, Family Assessment Device general functioning subscale; HRQOL, health-related quality of life; LOC, loss of consciousness; MRI, magnetic resonance imaging; RC, reliable change.
^a*P* < .05.

included age at injury, SES, Child Behavior Checklist Total T score, Brief Symptom Inventory General Severity Index T score, and Family Assessment Device general functioning subscale total score. A likelihood ratio test was used to test whether group differences varied over time; if it was not significant, a likelihood ratio test was used to test if the groups differed overall.

The next set of analyses examined how reliable change in postconcussive symptoms among children with mild TBI was related to HRQOL. Children with mild TBI who did and did not display reliable increases in either cognitive or somatic symptoms, or both, acutely or at 3 months postinjury were compared in mixed-models analyses predicting Child Health Questionnaire summary scores at 3 and 12 months postinjury. Separate analyses were conducted for the physical and psychosocial summary scores. The retrospective rating of preinjury HRQOL was treated as a covariate.

Lastly, logistic regression was used to examine the likelihood of educational intervention at 12 months as a function of reliable change in symptoms among children with mild TBI. Predictors included 2 dichotomous variables (ie, reliable change and status of educational intervention prior to injury) and an interaction term involving the 2 predictors.

RESULTS

GROUP DIFFERENCES IN RELIABLE CHANGE

Figure 1 displays the probability of reliable increases in cognitive symptoms as a function of group membership. Children with mild TBI are divided into those with and without LOC in Figure 1A and those with and with-

out abnormalities on MRI in Figure 1B. The groups differed significantly in both analyses, whether children with mild TBI were grouped according to LOC ($\chi^2=16.81$; *P* < .001) or MRI abnormality ($\chi^2=9.03$; *P* = .01).

Children with mild TBI and LOC were more likely than children with OI to display reliable increases in cognitive symptoms (**Table 2**). This was true at all occasions (initial assessment, odds ratio [OR] = 11.72; 95% CI, 2.25-60.99; 3 months, OR = 5.07; 95% CI, 1.03-24.83; 12 months, OR = 5.54, 95% CI, 1.14-26.96). When children with mild TBI were divided into those with and without MRI abnormalities, only those without abnormalities were more likely than children with OI to display reliable increases in cognitive symptoms.

Figure 2 displays the probability of reliable change in somatic symptoms as a function of group membership. Children with mild TBI are again grouped according to LOC (Figure 2A) and MRI abnormality (Figure 2B). In this case, group differences were significant but declined over time when children with mild TBI were grouped by LOC ($\chi^2=10.74$; *P* = .03) and to a lesser extent when they were grouped by MRI abnormality ($\chi^2=8.80$; *P* = .07).

Children with mild TBI, both those with and without LOC, showed significant declines over time in the likelihood of reliable change relative to children with OI (Table 2). Both groups were more likely to show reliable increases in somatic symptoms than children with OI at the initial assessment (LOC, OR = 16.25; 95% CI, 5.13-51.44; no LOC, OR = 7.78; 95% CI, 2.56-23.60) but not at 3 or 12 months postinjury.

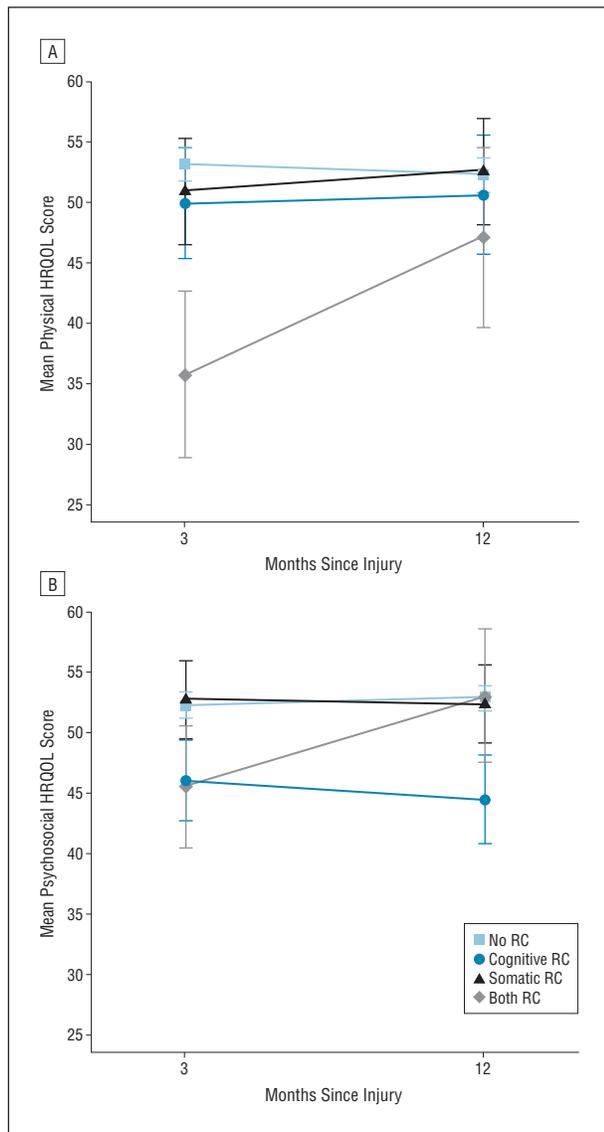


Figure 4. Mean ratings of physical health-related quality of life (HRQOL) (A) and psychosocial HRQOL (B) as a function of reliable change (RC) at 3 months postinjury among children with mild traumatic brain injury.

Similarly, children with mild TBI with and without MRI abnormalities also showed significant declines in the likelihood of reliable change in somatic symptoms. Both mild TBI groups were more likely to display reliable increases at the initial assessment than the OI group (MRI abnormal, OR=20.30; 95% CI, 5.51-74.80; MRI normal, OR=8.96; 95% CI, 3.06-26.25). Only children with abnormal MRIs showed a higher likelihood of reliable increases at 3 months postinjury (OR=5.19; 95% CI, 1.14-23.60).

FUNCTIONAL CONSEQUENCES OF RELIABLE CHANGE

Figure 3 displays the estimated means for HRQOL as a function of reliable change in symptoms at the initial assessment. Acute reliable change was a significant predictor of physical HRQOL ($\chi^2=12.98$; $P=.005$) but not of psychosocial HRQOL (**Table 3**). Among children with mild TBI, reliable increases in both cognitive and so-

matic symptoms at the initial assessment predicted significantly worse physical HRQOL at both 3 and 12 months than for children who did not display any reliable symptom increases (3 months, mean difference=6.72; 95% CI, 2.50-10.94; 12 months, mean difference=5.13; 95% CI, 0.81-9.46). Children who displayed reliable increases in only cognitive or somatic symptoms at the initial assessment did not show declines in physical HRQOL.

Figure 4 displays the estimated means for HRQOL as a function of reliable change in symptoms at 3 months postinjury. Reliable change at 3 months was a significant predictor of both physical and psychosocial HRQOL ($\chi^2=28.23$ and $\chi^2=37.71$, respectively; both $P<.001$) (**Table 3**). The relationship between reliable change and physical HRQOL varied across time ($\chi^2=10.34$; $P=.02$). Among children with mild TBI, reliable increases in both cognitive and somatic symptoms at 3 months postinjury predicted significantly worse physical HRQOL at 3 but not 12 months postinjury (3 months, mean difference=17.43; 95% CI, 10.37-24.49). Children who displayed reliable increases in only cognitive or somatic symptoms at 3 months did not show declines in physical HRQOL. Reliable increases in cognitive symptoms at 3 months predicted significantly worse psychosocial HRQOL at both 3 and 12 months (3 months, mean difference=6.27; 95% CI, 2.72-9.82; 12 months, mean difference=8.36; 95% CI, 4.54-12.18). Reliable changes in both cognitive and somatic symptoms predicted worse psychosocial HRQOL at 3 but not 12 months postinjury (3 months, mean difference=6.81; 95% CI, 1.59-12.02).

Finally, reliable increases in symptoms at the initial assessment did not predict the onset of educational intervention. However, reliable increases in somatic symptoms at 3 months postinjury predicted an increased rate of educational intervention among children not already receiving intervention at the time of their injury (OR=5.94; 95% CI, 1.54-22.86; $P=.01$). This was not true for children already receiving intervention at the time of their injury (Wald test for interaction=8.17; $P=.004$). Among children not receiving educational intervention at the time of injury, educational intervention was received at 12 months by 50% of children who displayed reliable increases in somatic symptoms but by only 14% of those who did not display reliable increases.

COMMENT

Children with mild TBI were more likely to exhibit reliable increases in both cognitive and somatic symptoms than children with OI. These differences became less common over time for somatic symptoms but persisted to 12 months postinjury for cognitive symptoms. Among children with mild TBI, reliable symptom increases were more common among children with LOC or abnormalities on neuroimaging. These results extend previous findings^{11,13} by showing that many individual children with mild TBI show substantial and persistent increases in postconcussive symptoms relative to their preinjury functioning.

Reliable change was significantly related to HRQOL as long as 12 months postinjury. Generally speaking, reli-

able change in symptoms acutely was less strongly related to HRQOL than reliable change at 3 months postinjury. Thus, persistent elevations in postconcussive symptoms increase the risk of lasting detrimental effects on both physical and psychosocial HRQOL. These findings extend previous research on HRQOL in childhood TBI^{32,33} by showing that while mild TBI per se may not affect HRQOL, it can do so indirectly when associated with persistent increases in postconcussive symptoms.

In a similar fashion, acute increases in postconcussive symptoms were not related to educational intervention, but reliable increases in somatic symptoms at 3 months postinjury did predict an increased likelihood of educational intervention. The results indicate that persistent postconcussive symptoms have functional consequences that are likely to reflect impairment in children's daily functioning.

One study limitation is the use of parent report measures for assessing both postconcussive symptoms and HRQOL, which introduces shared rater variance. Another potential limitation is that recruitment rates for the mild TBI and OI groups were both less than 50% and that attrition was greater among children of lower SES and minority status. However, nonparticipants did not differ from participants demographically, SES and minority status were covaried in data analyses, and the mixed-model analyses incorporated data from children who missed later assessments. A final shortcoming is the small number of children in the OI group who displayed reliable change. This is inherent in the computation of reliable change but limits statistical power. The small number of children with abnormal MRIs and receiving educational intervention also limited statistical power.

Our sample likely represents the more severe end of the spectrum of mild head injuries. In other words, based on our selection criteria, our sample does not encompass the entire population of children presenting to emergency departments for evaluation of minor closed-head trauma but instead involves only those with clear evidence of a mild TBI. However, our sample is similar in terms of injury severity to those recruited for larger epidemiological studies of children with mild TBI.⁴²

Health providers need to be able to identify children with mild TBI who are at risk for persistent postconcussive symptoms so that they can then target such children for appropriate management. Research is needed to clarify which injury- and noninjury-related factors increase the likelihood of reliable increases in postconcussive symptoms. The current research suggests that injury severity is one key factor. Advanced neuroimaging techniques may more clearly differentiate injury severity and its relationship to outcomes.⁴³

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Author Contributions: Dr Yeates had full access to all the data in the study and takes responsibility for the in-

tegrity of the data and the accuracy of the data analysis. *Study concept and design:* Yeates and Taylor. *Acquisition of data:* Yeates, Rusin, Bangert, Dietrich, Nuss, Wright, and Taylor. *Analysis and interpretation of data:* Yeates, Kaizar, and Taylor. *Drafting of the manuscript:* Yeates and Kaizar. *Critical revision of the manuscript for important intellectual content:* Yeates, Rusin, Bangert, Dietrich, Nuss, Wright, and Taylor. *Statistical analysis:* Yeates and Kaizar. *Obtained funding:* Yeates and Taylor. *Administrative, technical, and material support:* Yeates, Bangert, Dietrich, Nuss, Wright, and Taylor. *Study supervision:* Taylor. **Financial Disclosure:** None reported.

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REFERENCES

1. Bazarian JJ, McClung J, Shah MN, Cheng YT, Flesher W, Kraus J. Mild traumatic brain injury in the United States, 1998-2000. *Brain Inj.* 2005;19(2):85-91.
2. Faul M, Xu L, Wald MM, Coronado VG. *Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002-2006.* Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010.
3. McKinlay A. Controversies and outcomes associated with mild traumatic brain injury in childhood and adolescences. *Child Care Health Dev.* 2010;36(1):3-21.
4. Yeates KO. Mild traumatic brain injury and postconcussive symptoms in children and adolescents. *J Int Neuropsychol Soc.* 2010;16(6):953-960.
5. Carroll LJ, Cassidy JD, Peloso PM, et al; WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med.* 2004;43(suppl):84-105.
6. Satz P, Zaucha K, McCleary C, Light R, Asarnow R, Becker D. Mild head injury in children and adolescents: a review of studies (1970-1995). *Psychol Bull.* 1997;122(2):107-131.
7. Barlow KM, Crawford S, Stevenson A, Sandhu SS, Belanger F, Dewey D. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics.* 2010;126(2):e374-e381.
8. Hawley CA. Reported problems and their resolution following mild, moderate and severe traumatic brain injury amongst children and adolescents in the UK. *Brain Inj.* 2003;17(2):105-129.
9. Mittenberg W, Wittner MS, Miller LJ. Postconcussion syndrome occurs in children. *Neuropsychology.* 1997;11(3):447-452.
10. Ponsford J, Willmott C, Rothwell A, et al. Cognitive and behavioral outcome following mild traumatic head injury in children. *J Head Trauma Rehabil.* 1999;14(4):360-372.
11. Taylor HG, Dietrich A, Nuss K, et al. Post-concussive symptoms in children with mild traumatic brain injury. *Neuropsychology.* 2010;24(2):148-159.
12. Yeates KO, Luria J, Bartkowski H, Rusin J, Martin L, Bigler ED. Postconcussive symptoms in children with mild closed head injuries. *J Head Trauma Rehabil.* 1999;14(4):337-350.
13. Yeates KO, Taylor HG, Rusin J, et al. Longitudinal trajectories of postconcussive symptoms in children with mild traumatic brain injuries and their relationship to acute clinical status. *Pediatrics.* 2009;123(3):735-743.
14. Fay TB, Yeates KO, Taylor HG, et al. Cognitive reserve as a moderator of post-concussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. *J Int Neuropsychol Soc.* 2010;16(1):94-105.
15. Woodrome SE, Yeates KO, Taylor HG, et al. Coping strategies as a predictor of post-concussive symptoms in children with mild traumatic brain injury versus mild orthopedic injury. *J Int Neuropsychol Soc.* 2011;17(2):317-326.
16. McCrea M, Barr WB, Guskiewicz K, et al. Standard regression-based methods for measuring recovery after sport-related concussion. *J Int Neuropsychol Soc.* 2005;11(1):58-69.
17. Temkin NR, Heaton RK, Grant I, Dikmen SS. Detecting significant change in neuropsychological test performance: a comparison of four models. *J Int Neuropsychol Soc.* 1999;5(4):357-369.
18. Ouimet LA, Stewart A, Collins B, Schindler D, Bielajew C. Measuring neuropsychological change following breast cancer treatment: an analysis of statistical models. *J Clin Exp Neuropsychol.* 2009;31(1):73-89.

19. McSweeney AJ, Naugle RI, Chelune GJ, Luders H. "T scores for change": an illustration of a regression approach to depicting change in clinical neuropsychology. *Clin Neuropsychol*. 1993;7(3):300-312. <http://www.tandfonline.com/doi/abs/10.1080/13854049308401901>.
20. Yeates KO, Taylor HG. Neurobehavioural outcomes of mild head injury in children and adolescents. *Pediatr Rehabil*. 2005;8(1):5-16.
21. Rimel RW, Giordani B, Barth JT, Boll TJ, Jane JA. Disability caused by minor head injury. *Neurosurgery*. 1981;9(3):221-228.
22. Barry CT, Taylor HG, Klein S, Yeates KO. The validity of neurobehavioral symptoms reported in children after traumatic brain injury. *Child Neuropsychol*. 1996; 2:213-226.
23. Teasdale G, Jennett B. Assessment of coma and impaired consciousness: a practical scale. *Lancet*. 1974;2(7872):81-84.
24. American Association for Automotive Medicine. *The Abbreviated Injury Scale (AIS): 1990 Revision*. Des Plaines, IL: American Association for Automotive Medicine; 1990.
25. Stevens G, Cho JH. Socioeconomic indexes and the new 1980 census occupational classification scheme. *Soc Sci Res*. 1985;14(2):142-168. doi:10.1016/0049-089X(85)90008-0.
26. Osler T, Baker SP, Long WA. A modification of the Injury Severity Score that both improves accuracy and simplifies scoring. *J Trauma*. 1997;43(6):922-925, discussion 925-926.
27. Ayr LK, Yeates KO, Taylor HG, Browne M. Dimensions of postconcussive symptoms in children with mild traumatic brain injuries. *J Int Neuropsychol Soc*. 2009; 15(1):19-30.
28. McCauley SR, Wilde EA, Anderson VA, et al. Recommendations for the use of common outcome measures in pediatric traumatic brain injury research [published online August 24, 2011]. *J Neurotrauma*. doi:10.1089/neu.2011.1838.
29. Landgraf JM, Abetz L, Ware JE. *Child Health Questionnaire (CHQ): A User's Manual*. Boston, MA: HealthAct; 1996.
30. McCarthy ML. Measuring children's health-related quality of life after trauma. *J Trauma*. 2007;63(6)(suppl):S122-S129, discussion S130-S135.
31. Palermo TM, Long AC, Lewandowski AS, Drotar D, Quittner AL, Walker LS. Evidence-based assessment of health-related quality of life and functional impairment in pediatric psychology. *J Pediatr Psychol*. 2008;33(9):983-996, discussion 997-998.
32. McCarthy ML, MacKenzie EJ, Durbin DR, et al; Children's Health After Trauma Study Group. Health-related quality of life during the first year after traumatic brain injury. *Arch Pediatr Adolesc Med*. 2006;160(3):252-260.
33. Stancin T, Drotar D, Taylor HG, Yeates KO, Wade SL, Minich NM. Health-related quality of life of children and adolescents after traumatic brain injury. *Pediatrics*. 2002;109(2):E34.
34. Taylor HG, Yeates KO, Wade SL, Drotar D, Stancin T, Monpetite M. Long-term educational interventions after traumatic brain injury in children. *Rehabil Psychol*. 2003;48(4):227-236. doi:10.1037/0090-5550.48.4.227.
35. Yeates KO, Taylor HG. Behavior problems in school and their educational correlates among children with traumatic brain injury. *Exceptionality*. 2006;14(3):141-154. doi:10.1207/s15327035ex1403_3.
36. Achenbach TM. *Integrative Guide for the 1991 CBCL/4-18, YSR, and TRF Profiles*. Burlington: University of Vermont, Department of Psychiatry; 1991.
37. Derogatis L, Spencer P. *The Brief Symptom Inventory: Administration, Scoring, and Procedures Manual I*. Baltimore, MD: Clinical Psychology Research; 1982.
38. Derogatis LR, Melisaratos N. The Brief Symptom Inventory: an introductory report. *Psychol Med*. 1983;13(3):595-605.
39. Byles J, Byrne C, Boyle MH, Offord DR. Ontario Child Health Study: reliability and validity of the general functioning subscale of the McMaster Family Assessment Device. *Fam Process*. 1988;27(1):97-104.
40. Miller IW, Bishop DS, Epstein NB, Keitner GI. The McMaster Family Assessment Device: reliability and validity. *J Marital Fam Ther*. 1985;11(4):345-356. doi:10.1111/j.1752-0606.1985.tb00028.x.
41. Taylor HG, Yeates KO, Wade SL, Drotar D, Klein SK, Stancin T. Influences on first-year recovery from traumatic brain injury in children. *Neuropsychology*. 1999; 13(1):76-89.
42. Osmond MH, Klassen TP, Wells GA, et al; Pediatric Emergency Research Canada (PERC) Head Injury Study Group. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. *CMAJ*. 2010;182(4):341-348.
43. Ashwal S, Tong KA, Obenaus A, Holshouser BA. Advanced neuroimaging techniques in children with traumatic brain injury. In: Anderson VA, Yeates KO, eds. *New Directions in Pediatric Traumatic Brain Injury: Multidisciplinary and Translational Perspectives*. New York, NY: Oxford University Press; 2010:68-93.