

# Mild Traumatic Brain Injuries and Risk for Affective and Behavioral Disorders

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abstract

**OBJECTIVES:** Recent studies document an association between mild traumatic brain injuries (mTBIs) in children and postinjury psychiatric disorders. However, these studies were subject to limitations in the design, lack of long-term follow-up, and poorly defined psychiatric outcomes. This study determines the incidence and relative risk of postinjury new affective and behavior disorders 4 years after mTBIs.

**METHODS:** A cohort study of mTBI cases and matched comparisons within an integrated health care system. The mTBI group included patients  $\leq 17$  years of age, diagnosed with mTBI from 2000 to 2014 ( $N = 18\,917$ ). Comparisons included 2 unexposed patients ( $N = 37\,834$ ) per each mTBI-exposed patient, randomly selected and matched for age, sex, race/ethnicity, and date of medical visit (reference date to mTBI injury). Outcomes included a diagnosis of affective or behavioral disorders in the 4 years after mTBI or the reference date.

**RESULTS:** Adjusted risks for affective disorders were significantly higher across the first 3 years after injury for the mTBI group, especially during the second year, with a 34% increase in risk. Adjusted risks for behavioral disorders were significant at years 2 and 4, with up to a 37% increase in risk. The age group with the highest risk for postinjury affective and behavioral disorders was 10- to 13-year-old patients.

**CONCLUSIONS:** Sustaining an mTBI significantly increased the risks of having a new affective or behavioral disorder up to 4 years after injury. Initial and ongoing screening for affective and behavior disorders following an mTBI can identify persistent conditions that may pose barriers to recovery.



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**WHAT'S KNOWN ON THIS SUBJECT:** Recent studies document an association between mild traumatic brain injuries in children and the development of postinjury psychiatric disorders. However, these studies were subject to limitations in the design, lack of long-term follow-up, and poorly defined psychiatric outcomes.

**WHAT THIS STUDY ADDS:** Sustaining an mTBI increased the risk of new affective or behavioral disorders up to 4 years postinjury, especially in children aged 10–13 years old. Early screening after an mTBI can identify persistent conditions that may pose barriers to recovery.

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Traumatic brain injury (TBI) in children has been associated with an increased risk of developing psychiatric disorders.<sup>1-7</sup> Although most studies examined children with moderate to severe TBI, recent reports indicate increased risk of psychiatric symptoms after mild TBI (mTBI).<sup>3,4,6-9</sup> These symptoms may persist up to 3 years after injury,<sup>3,4,8,9</sup> and are more likely to occur in children with a history of a behavior problem or psychiatric disorder.<sup>3,4,8,9</sup>

Psychiatric effects of mTBI can include affective and behavior disorders. Affective disorders include depression, anxiety, posttraumatic stress disorder, acute stress, and adjustment disorders.<sup>8</sup> Behavioral disorders include conduct disorder, oppositional defiant disorder (ODD), and attention deficit hyperactivity disorder (ADHD).<sup>6,9-11</sup> The literature on behavioral diagnoses of non-ADHD after mTBI is limited, inconsistent, and the findings are not clinically significant. Although 1 study reported that children younger than age 10 years at the time of injury were more likely to have behavioral problems 1 year after mTBI,<sup>6</sup> another study on conduct disorders 6 and 12 months after mild, moderate, and severe TBI found no conduct disorders at either point of follow-up.<sup>10,11</sup> Although ADHD has been associated with TBI in children, this relationship is complex, lacks strong evidence for causality, and is complicated by those children diagnosed with ADHD preinjury as well as family and environmental circumstances.<sup>12,13</sup> Although only 1 study reported that TBI was associated with an ADHD diagnosis 5 to 10 years after injury in young children,<sup>14</sup> another found no significant risk for developing ADHD after mTBI.<sup>15</sup>

The incidence and impact of affective and behavior disorders in the pediatric mTBI population within an integrated health care system is unclear. Given that mTBI represents at least 75% of all TBIs annually, there is a high likelihood that the incidence of a cooccurring mental health condition is significant.<sup>16</sup> We conducted a longitudinal cohort study comparing psychiatric outcomes (affective disorders [depressive, anxiety, and adjustment disorders] and behavioral disorders [conduct, ODD, and ADHD]) of pediatric patients who acquired an mTBI to a matched cohort without brain injuries within an integrated health care system. We predicted that children with an mTBI would have a significantly higher risk of developing a new psychiatric disorder 4 years after injury compared with children without mTBI. This follow-up period was selected based on the studies reviewed previously that indicate these disorders may emerge and persist up to 3 years after mTBI.

## METHODS

### Design and Setting

This study is an observational matched cohort design using electronic health records (EHRs) within an integrated

health care system based in Northern California. The reference dates for the cohort entry were January 1, 2001, through December 31, 2014, with a 1-year lookback period and a 4-year follow-up period. The institutional review board of the integrated health care system approved this study with a waiver of consent.

### Participants

#### *mTBI Group*

Eligible patients were aged 17 years and younger with a primary diagnosis of mTBI treated in the emergency department (ED), urgent care, or any outpatient clinic within the integrated health care system. The diagnoses codes for mTBI using the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) included: postconcussion syndrome, 310.2; concussion with no loss of consciousness, 850.0; concussion with brief loss of consciousness, 850.1; concussion with loss of consciousness of 30 minutes or less, 850.11; and concussion unspecified, 850.9.

We used the diagnostic criteria based on the Centers for Disease Control and Prevention Pediatric Mild TBI Guideline workgroup.<sup>17</sup> A TBI was considered mild if ICD-9-CM codes indicated brief (<30 minutes) or no loss of consciousness and no documented traumatic intracranial lesions. The reference date in the mTBI group was the initial mTBI diagnosis date. Patients were excluded if they<sup>1</sup>: were aged 18 years or older at mTBI onset<sup>2</sup>; had a health plan membership (health insurance coverage) for less than 9 months in any 12-month period from lookback through follow-up<sup>3</sup>; died anytime during 4-year follow-up; and<sup>4</sup> had postconcussion syndrome paired with any ICD-9-CM diagnoses more severe than an mTBI.

#### *Comparison Group*

Eligible patients were aged 17 years and younger who had medical visits in the ED, urgent care, or any outpatient clinic within the integrated health care system and<sup>1</sup>: did not have a TBI diagnosis between 2000 and 2018<sup>2</sup>; had active health plan membership at least 9 months during each calendar year from 2000 to 2018; and were alive as of 2018.<sup>3</sup> We used Mahalanobis distance function for each patient with mTBI to identify 2 within the comparison group who matched according to age, sex, and race/ethnicity.<sup>18,19</sup> Patients in the comparison group eligible for the matching were those with eligible medical visits in the month of the reference date (corresponding to the mTBI date in the mTBI group). Because a patient could have medical visits in multiple months, matching was completed month by month from year 2001 to year 2014 to prevent duplication. Any patient selected as a comparison in a particular month was removed from the comparison eligibility pool for subsequent months.

## Variables

### Exposure

The independent variable is a binary variable indicating exposure to mTBI and was determined based on ICD-9-CM diagnosis codes, as specified previously.

### Psychiatric Disorders

Primary outcomes were new affective and behavioral disorders (Table 1) diagnosed anytime during the 4-year follow-up. We used diagnoses from either the ICD-9-CM, the International Classification of Diseases, Tenth Revision, Clinical Modification, or the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision, and Fifth Edition,<sup>20,21</sup> whichever were assigned to a medical visit in the EHR during study observation.

### Demographics and Clinical History

Demographic data included age, race/ethnicity, sex, health plan benefit (eg, managed Medicare/Medicaid, commercial, self-pay), and low-income residence (residential address in a census block with  $\geq 20\%$  households below the federal poverty level). For clinical baseline data, we included affective and behavioral disorders diagnosed during the look-back period.

### Mortality Status

We determined deaths using a mortality database of deaths recorded by the integrated health care system and California state death records. We also reviewed health care utilization records to confirm the mortality status.

### Bias Mitigation

To ensure the accuracy of data extraction, study investigators (R.D. and B.R.T.) conducted structured EHR reviews on a random sample of 2% of patients from each study group. Electronic data extraction was adjusted as necessary before compiling the final study cohort (eg, cases were excluded when the primary mTBI diagnosis was documented outside the integrated health care system and without internal follow-up medical visit within 7 days). Additionally, the integrated health care system transitioned to an electronic documentation system (EHR implementation) about halfway through the cohort entry. We adjusted all regression analyses for pre versus post EHR implementation to control for pre- versus postimplementation variability in the standardization of diagnoses. In terms of demographics, there is evidence for higher risks of injury and adverse health outcomes after an mTBI among non-Hispanic Black children and Hispanic children.<sup>22,23</sup> However, these risks may also be a proxy for, or correlated with, socioeconomic differences. Therefore, in our study, we controlled for both race/ethnicity in the matching model and with income levels in the regression model. Finally, we

documented the proportion of psychiatric diagnoses made by mental health professionals versus other specialties to determine if most were made by clinicians trained to recognize, diagnose, and manage these disorders.

### Statistical Methods

Descriptive statistics (frequencies and percentages) describe the demographic and clinical characteristics of the cohort at baseline.  $\chi$ -square tests were used to compare previous affective and behavioral disorders preceding mTBI or reference date. We calculated unadjusted incidence rates of psychiatric disorders (affective/behavioral disorders and by subtypes) over the 4-year follow-up and by the end of each follow-up year for each cohort group overall and by age groups (0–5, 6–9, 10–13, and 14–17 years). Adjusted relative risk estimates of psychiatric disorders comparing the mTBI group with the comparison group were computed using generalized linear models with logit link function for fixed-interval, interval-censored data, controlled for age, sex, race, low-income residence, and EHR implementation period. These models were repeated for each age group. Patients with preexisting affective and behavioral disorders were excluded from the analyses on outcomes.

All analyses were performed using SAS software version 9.4 (SAS, Cary, North Carolina) and conducted to test for significance at  $\alpha = .05$ . Bonferroni error correction was used when multiple comparisons were conducted within each omnibus test to mitigate for inflation of type I error. The study outcomes had 8 multiple comparisons that may be correlated because of comorbid psychiatric disorders; therefore, our threshold for reporting a significant finding was  $P < .00625$ .

## RESULTS

### Cohort Characteristics

A total of 2 139 984 pediatric patients received care at EDs, urgent care, and outpatient clinics in the integrated health care system between 2001 and 2014. Figure 1 summarizes the cohort selection criteria for both the mTBI group and the comparison group. The final mTBI group consisted of 18 917 patients who received their mTBI diagnosis at EDs (38%), urgent care (14%), and outpatient clinics (44%; predominantly at a pediatric visit), and unspecified (4%). These mTBI patients were matched to 37 834 non-brain-injured pediatric patients in a 2:1 matching ratio.

Table 2 describes the characteristics of the study cohort. Patients were predominantly 14 to 17 years old (48%), followed by the age 10–13 (28%), 6–9 (13%), and 0–5 (11%) age groups. Patients were also predominantly male (64%) and had racial/ethnic group distributions that were reflective of the population in Northern California. Less than 10% of the cohort qualified as being

TABLE 1 Psychiatric Diagnoses for Affective and Behavioral Disorders		
ICD-10 CM	ICD-9 CM	DSM-IV-TR/DSM-5 Diagnosis Description
<b>Affective disorders</b>		
Depressive disorders		
F06.30	293.83	Depressive Disorder Due to Another Medical Condition <sup>a,b</sup>
F06.31		With depressive features <sup>a,b</sup>
F06.32		With major depressive-like episode <sup>a,b</sup>
F06.34		With mixed features <sup>a,b</sup>
F32.9	296.20	Major Depressive Disorder, Single Episode Unspecified <sup>a,b</sup>
F32.0	296.21	Major Depressive Disorder, Single Episode Mild <sup>a,b</sup>
F32.1	296.22	Major Depressive Disorder, Single Episode Moderate <sup>a,b</sup>
F32.2	296.23	Major Depressive Disorder, Single Episode Severe <sup>a,b</sup>
F32.3	296.24	With psychotic features <sup>a,b</sup>
F32.4	296.25	In partial remission <sup>a,b</sup>
F32.5	296.26	In full remission <sup>a,b</sup>
F33.9	296.30	Major Depressive Disorder, Recurrent Unspecified <sup>a,b</sup>
F33.0	296.31	Major Depressive Disorder, Recurrent Mild <sup>a,b</sup>
F33.1	296.32	Major Depressive Disorder, Recurrent Moderate <sup>a,b</sup>
F33.2	296.33	Major Depressive Disorder, Recurrent Severe <sup>a,b</sup>
F33.3	296.34	With psychotic features <sup>a,b</sup>
F33.41	296.35	In partial remission <sup>a,b</sup>
F33.42	296.36	In full remission <sup>a,b</sup>
F32.89	296.82	Atypical Depressive Disorder <sup>a,b</sup>
F39	296.9	Mood Disorder NOS <sup>a,b</sup>
F34.1	300.4	Persistent Depressive Disorder (Dysthymia) <sup>a,b</sup>
F32.9	311	Depressive Disorder NOS/Unspecified <sup>a,b</sup>
F32.8	311	Depressive Disorder Other Specified <sup>a,b</sup>
F34.8	296.99	Disruptive Mood Dysregulation Disorder <sup>a,b</sup>
Anxiety disorders		
F06.4	293.84	Anxiety Disorder Due to Another Medical Condition <sup>a,c</sup>
F41.9	300.00	Anxiety Disorder Other Specified <sup>a,c</sup>
F41.8	300.09	Anxiety Disorder Unspecified <sup>a,c</sup>
F41.0	300.01	Panic Disorder Without Agoraphobia <sup>a,c</sup>
F41.1	300.02	Generalized Anxiety Disorder <sup>a,c</sup>
	300.29	Specific Phobia <sup>a,c</sup>
F40.218	300.29	Animal <sup>a,c</sup>
F40.228	300.29	Natural Environment <sup>a,c</sup>
F40.23x	300.29	Blood-injection-injury <sup>a,c</sup>
F40.248	300.29	Situational <sup>a,c</sup>
F40.298	300.29	Other <sup>a,c</sup>
F40.8	300.29	Other Isolated or Simple Phobia <sup>a,c</sup>
F40.9	300.2	Phobic Disorder Unspecified <sup>a,c</sup>
F40.01	300.21	Agoraphobia With Panic Attacks <sup>a,c</sup>
F40.02	300.22	Agoraphobia Without Panic Attacks <sup>a,c</sup>
F40.10	300.23	Social Anxiety Disorder/Social Phobia <sup>a,c</sup>
F42.9	300.3	Obsessive Compulsive Disorder <sup>a,c</sup>
F43.0	300.8	Acute reaction to Stress/Acute Stress Disorder <sup>a,c</sup>
F43.0	308.4	Mixed Disorders as Reaction to Stress <sup>a,c</sup>
R45.7	308.9	Unspecified Reaction to Stress <sup>a,c</sup>
F43.10	309.81	Post-Traumatic Stress Disorder <sup>a,c</sup>
F43.8	309.89	Other Specified Trauma and Stressor Related Disorder <sup>a,c</sup>
F43.20	309.9	Other Unspecified Trauma and Stressor Related Disorder <sup>a,c</sup>
F42	300.3	Other Specified/Unspecified Obsessive-Compulsive and Related Disorder <sup>a,c</sup>
F06.8	294.8	Obsessive-Compulsive and Related Disorder Due to Another Medical Condition <sup>a,c</sup>
F45.22	300.7	Body Dysmorphic Disorder <sup>a,c</sup>

TABLE 1 Continued		
ICD-10 CM	ICD-9 CM	DSM-IV-TR/DSM-5 Diagnosis Description
<b>Affective disorders</b>		
Adjustment disorders		
F43.21	309.0	Adjustment Reaction/Disorder With Depressed Mood/Brief Depressive Reaction <sup>a,d</sup>
F43.22	309.24	Adjustment Reaction/Disorder With Anxiety <sup>a,d</sup>
F43.23	309.28	Adjustment Reaction/Disorder With Mixed Anxiety and Depressed Mood <sup>a,d</sup>
F43.8	309.82	Adjustment Reaction With Physical Symptoms <sup>a,d</sup>
F43.8	309.83	Adjustment Reaction With Withdrawal <sup>a,d</sup>
F43.20	309.9	Adjustment Disorder Unspecified <sup>a,d</sup>
F43.24	309.3	Adjustment Disorder With Disturbance of Conduct <sup>a,d</sup>
F43.25	309.4	Adjustment Disorder With Mixed Disturbance of Emotions and Conduct <sup>a,d</sup>
Behavior disorders		
Conduct disorders		
F91.0	312.89	Conduct Disorder Confined to Family Context <sup>e,f</sup>
F91.8	312.89	Other Specified Disruptive, Impulse-Control, and Conduct Disorder <sup>e,f</sup>
F91.2	312.82	Conduct Disorder, Adolescent-Onset Type <sup>e,f</sup>
F91.2	312.20	Socialized Conduct Disorder, Unspecified <sup>e,f</sup>
F91.1	312.81	Conduct Disorder, Childhood-Onset Type <sup>e,f</sup>
F91.1	312.00	Undersocialized Conduct Disorder, Aggressive Type, Unspecified <sup>e,f</sup>
F91.1	312.10	Undersocialized Conduct Disorder, Unaggressive Type, Unspecified <sup>e,f</sup>
F91.9	312.9	Unspecified Disruptive, Impulse-Control, and Conduct Disorder <sup>e,f</sup>
F91.3	313.81	Oppositional Defiant Disorder <sup>e,f</sup>
F63.81	312.34	Intermittent Explosive Disorder <sup>e,f</sup>
Attention-deficit/hyperactivity disorders		
F90.2	314.01	Attention Deficit/Hyperactivity Disorder, Combined Presentation <sup>e,g</sup>
F90.0	314.00	Attention Deficit/Hyperactivity Disorder, Predominantly Inattentive Presentation <sup>e,g</sup>
F90.1	314.01	Attention Deficit/Hyperactivity Disorder, Predominantly Hyperactive/Impulsive Presentation <sup>e,g</sup>
F90.8	314.2	Attention-Deficit/Hyperactivity Disorder, Other Type/Hyperkinetic Conduct Disorder <sup>e,g</sup>
F90.8	314.0	Attention-Deficit/Hyperactivity Disorder <sup>e,g</sup>
F90.8	314.01	Other Specified Attention-Deficit/Hyperactivity Disorder <sup>e,g</sup>
F90.9	314.01	Unspecified Attention-Deficit/Hyperactivity Disorder <sup>e,g</sup>
F90.9	314.9	Attention-Deficit/Hyperactivity Disorder, Unspecified Type/Unspecified Hyperkinetic Syndrome <sup>e,g</sup>
R41.840	799.51	Attention and Concentration Deficit <sup>e,g</sup>

DSM-IV-TR, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision; DSM-5, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; ICD-9-CM, International Classification of Disease, Ninth Revision, Clinical Modification; ICD-10 CM, International Classification of Disease, Tenth Revision, Clinical Modification; NOS, not otherwise specified.

<sup>a</sup> Diagnoses included in any affective disorder.  
<sup>b</sup> Diagnoses included in depressive disorders.  
<sup>c</sup> Diagnosis included in anxiety disorders.  
<sup>d</sup> Diagnoses included in adjustment disorders.  
<sup>e</sup> Diagnoses included in any behavioral disorder.  
<sup>f</sup> Diagnoses included in conduct disorder.  
<sup>g</sup> Diagnosis included in attention deficit hyperactivity disorder.

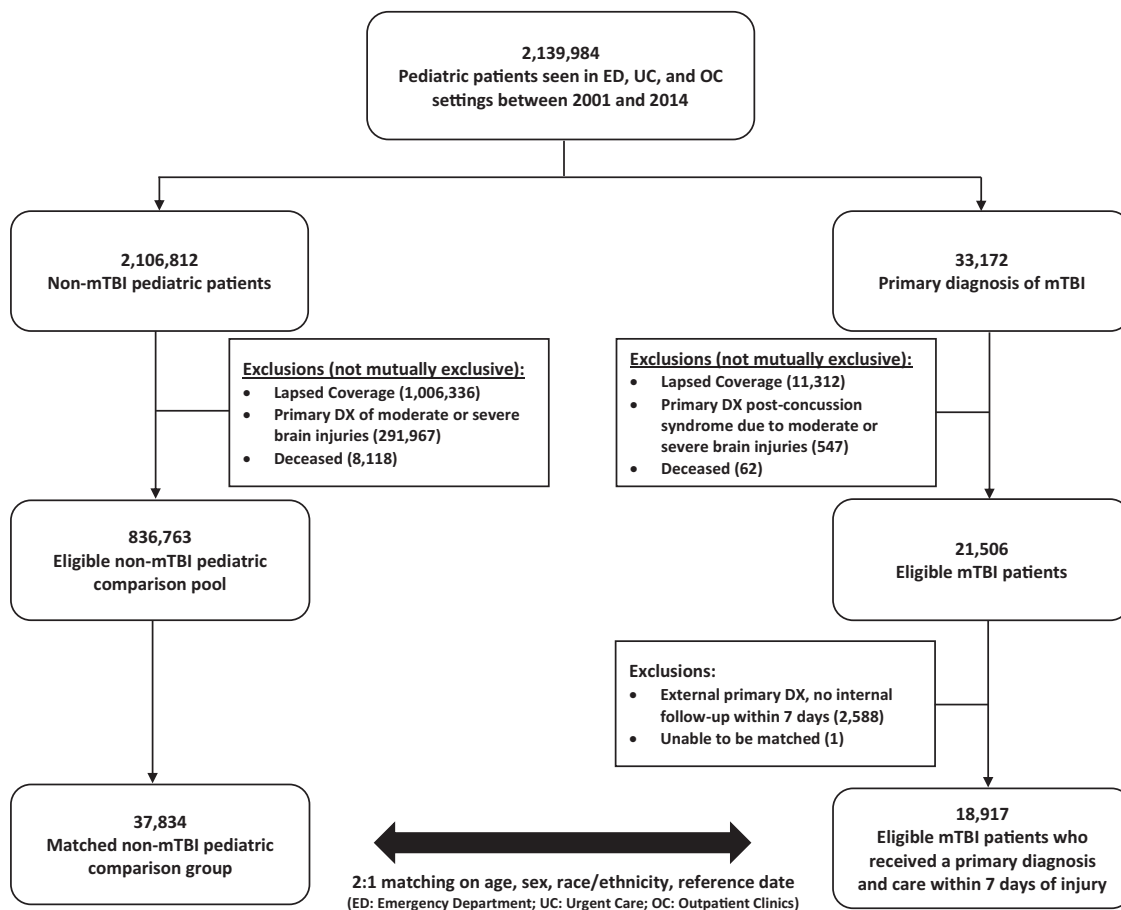
from low-income households. Twelve percent of the non-injured comparisons and 8% of the mTBI patients had a previous affective disorder ( $P < .001$ ). Similarly, 10% of the noninjured comparisons and 7% of the mTBI patients had a previous behavioral disorder ( $P < .001$ ).

### Incidence and Risk for Postinjury Affective Disorders

Psychiatry and behavioral health clinicians diagnosed most affective disorders (84%). Table 3 summarizes the individual 4-year and overall incidence and adjusted risk of affective

disorders. The mTBI group was 25% more likely to be diagnosed with an affective disorder during the overall 4-year study follow-up period; the adjusted risk was significant across the first 3 years. Specifically, these diagnoses were only significant in the 10 to 13 and 14 to 17 year age groups, with the former being 48% more likely to be diagnosed with any affective disorders at year 2.

The overall adjusted risk for post mTBI depressive disorders was 17% more likely in the mTBI group and was sustained over the first 2 years after injury. However,



**FIGURE 1** Summary of the cohort selection criteria for the mTBI and noninjured comparison groups. DX, diagnosis; mTBI, mild traumatic brain injury.

this increased risk was only significant in the 10 to 13 year age group, which was approximately 40% more likely to be diagnosed with a depressive disorder during the first 2 years after mTBI. For anxiety disorders, the mTBI group was 14% more likely to be diagnosed across all 4 years in aggregate, and this adjusted risk was only sustained during the second year after mTBI. The 10 to 13 year age group was most at risk, being 42% more likely to receive a diagnosis for anxiety disorders 2 years after mTBI. The mTBI patients in the 14 to 17 year age group were 13% more likely to be diagnosed with anxiety disorders when aggregated over 4 years, but effect sizes were not significant when analyzed for each of these years individually. Adjustment disorders were 27% more likely in the mTBI group, and this effect was sustained over the first 2 years after mTBI. Although mTBI patients in the 10 to 13 year age group were 39% more likely to have an adjustment disorder, this risk was only sustained during the first year after mTBI. The 14 to 17 year age group was approximately 30% more likely to be diagnosed with adjustment disorders over the first 2 years after mTBI. Finally, the 0 to 5 year olds with mTBI had a

significantly increased risk for adjustment disorders at year 4. However, the differences between the small sample sizes in this age group resulted in a dramatically high relative risk, although absolute numbers of cases were low.

### Incidence and Risk for Postinjury Behavioral Disorders

Psychiatry and behavioral health clinicians predominantly (70%) diagnosed behavioral disorders. Table 4 summarizes the individual 4-year and overall incidence and adjusted risk of behavioral disorders. Overall, the mTBI group was 18% more likely to be diagnosed with any behavioral disorders during the 4-year follow-up. An increase in risk during the second and fourth year was also observed, with the mTBI group being 21% and 37% more likely to be diagnosed with any behavioral disorders, during the second and fourth years, respectively. However, that trend was not observed when examined within age groups. Only the 10 to 13 year age group had significant risk and was up to 50% more likely to be diagnosed with any behavioral disorders during the first 2 years after mTBI.

**TABLE 2** Demographic Characteristics of the Study Cohort

Variable	Comparison <sup>a</sup> N = 37 834	mTBI N = 18 917	P	Odds Ratio (95% CI)
Age groups, y (n)			1.000	N/A
0–5	11 (4338)	11 (2169)		
6–9	13 (4792)	13 (2396)		
10–13	28 (10 476)	28 (5238)		
14–17	48 (18 228)	48 (9144)		
Sex (n)			1.000	N/A
Female	36 (13 530)	36 (6756)		
Male	64 (24 304)	64 (12 152)		
Race/ethnicity (n)			1.000	N/A
White (non-Hispanic)	49 (18 678)	49 (9339)		
Hispanic/Latino	24 (8949)	24 (4476)		
Asian/Pacific Islander	10 (3608)	10 (1807)		
Black/African American	9 (3493)	9 (1746)		
Other race/ethnicity	8 (3106)	8 (1549)		
Low-income households - % (n)	9 (3574)	8 (1552)	<.0001 <sup>b</sup>	0.86 (0.81–0.91) <sup>b</sup>
Previous diagnoses (n)				
Affective disorders	12 (4449)	8 (1489)	<.0001 <sup>b</sup>	0.64 (0.60–0.68) <sup>b</sup>
Behavioral disorders	10 (3643)	7 (1273)	<.0001 <sup>b</sup>	0.68 (0.63–0.72) <sup>b</sup>

mTBI, mild traumatic brain injury; N/A, not available.  
<sup>a</sup> Two comparison patients were selected for each mTBI patient. Comparisons have the same “reference date” (ie, corresponding to the injury date of the paired mTBI patient).  
mTBI patients were matched to their respective comparisons using Mahalanobis distance function based on sex, age, and race/ethnicity.  
<sup>b</sup> Statistically significant risk ratios ( $P < .05$ ).

The risk for a post-mTBI conduct disorder was overall 31% more likely in the mTBI group with a sustained risk only during 1-year after injury. The 10 to 13 year age group was the only group with a significant risk for conduct disorders, being overall 64% more likely to be diagnosed, with increases in risk at years 2 and 3 after mTBI (at 75% and 117% increase in risk, respectively). Although these risk ratios were large in magnitude, the sample sizes in these groups were very small. A similar trend was observed with small sample sizes with ODD, with the 10 to 13 year age group being 34% more likely to receive this diagnosis after mTBI, with only a significant elevated risk at year 2 after injury. Finally, the mTBI group was 17% overall more likely to be diagnosed with ADHD, with the risk only significantly emerging in year 4. The 10 to 13 year age group was the only one with a significant risk (27% more likely) for being diagnosed with ADHD after mTBI.

## DISCUSSION

The current study examined new mental health sequelae of mTBI in pediatric patients in an integrated health system in Northern California. In general, sustaining an mTBI significantly increased the risk of being diagnosed with a new affective disorder 4 years after injury. These findings clarify and expand on previous studies of the post-mTBI development of psychiatric disorders in children and adolescents.<sup>8</sup> Our results show an

elevated risk of developing an affective disorder diagnosis after an mTBI in children as age increases and is especially pronounced in the 10- to 13-year-old age group. This age group had the highest risk of developing depressive, anxiety, and adjustment disorders. These findings are consistent with Massagli et al,<sup>4</sup> with the exception of adjustment disorders in the 0 to 5 year age group. We did not find any significant differences in new psychiatric diagnoses in children younger than age 10 years. This is most likely because of a reluctance among clinicians for establishing an affective disorder diagnosis in younger children. In our post hoc chart reviews of the 0 to 5 year olds who had a significant risk for adjustment disorders, we did indeed find that the latency between injury and a psychiatric diagnosis was on average 3.5 years later, and the majority of these diagnoses were made when they were older than 5 years of age.

Our study showed that sustaining an mTBI also significantly increased the likelihood of a new behavioral disorder diagnosis during the 4 years after injury. The risk for developing any behavioral disorder was highest during the first 2 years after injury, and specifically for the 10 to 13 year old age group only. However, except for ADHD, which was a significant risk only during the fourth year, the absolute numbers of cases for all other disorders were low and therefore consistent with previous findings that diagnosed behavioral disorders were rare and not likely to emerge as a new diagnosis after an mTBI.<sup>10,11</sup>

**TABLE 3** Incidence and Adjusted Risk<sup>a</sup> of Affective Disorders During 4 Years After mTBI Versus Comparisons

Psychiatric Diagnoses % (n)	Study Groups	Overall	0–12 mo	13–24 mo	25–36 mo	37–48 mo
Any affective disorder	Comparisons	16.9% (5656)	5.3% (1780)	4.3% (1370)	4.2% (1281)	4.2% (1225)
	mTBI	20.1% (3553)	6.6% (1141)	5.8% (936)	5.1% (783)	4.8% (693)
	<i>P</i>	<.0001 <sup>b</sup>	<.0001 <sup>b</sup>	<.0001 <sup>b</sup>	<.0001 <sup>b</sup>	.0098
	RR (95% CI)	1.25 (1.19–1.31)	1.23 (1.14–1.33)	1.34 (1.23–1.46)	1.22 (1.11–1.33) <sup>b</sup>	1.13 (1.03–1.25)
0–5 y old	Comparisons	4.3% (187)	0.6% (27)	0.9% (38)	1.6% (67)	1.3% (55)
	mTBI	5.5% (118)	0.8% (18)	1.4% (29)	1.2% (26)	2.2% (45)
	<i>P</i>	.0393	.3167	.1075	.2999	.0093
	RR (95% CI)	1.28 (1.01–1.63)	1.36 (0.74–2.47)	1.50 (0.92–2.45)	0.78 (0.50–1.24)	1.70 (1.14–2.53)
6–9 y old	Comparisons	12.6% (563)	3.6% (162)	3.3% (143)	3.0% (125)	3.3% (133)
	mTBI	14.0% (321)	4.3% (99)	3.3% (73)	4.1% (86)	3.1% (63)
	<i>P</i>	.1116	.1722	.9983	.0309	.7051
	RR (95% CI)	1.13 (0.97–1.31)	1.19 (0.92–1.54)	1.00 (0.75–1.33)	1.36 (1.03–1.80)	0.94 (0.69–1.28)
10–13 y old	Comparisons	18.8% (1746)	5.2% (485)	4.7% (410)	5.0% (421)	5.4% (430)
	mTBI	23.6% (1137)	6.7% (325)	6.7% (300)	6.5% (274)	6.1% (238)
	<i>P</i>	<.0001 <sup>b</sup>	.0002 <sup>b</sup>	<.0001 <sup>b</sup>	.0003 <sup>b</sup>	.1017
	RR (95% CI)	1.34 (1.23–1.46)	1.31 (1.14–1.52)	1.48 (1.27–1.72)	1.34 (1.14–1.57) <sup>b</sup>	1.15 (0.97–1.35)
14–17 y old	Comparisons	20.7% (3160)	7.2% (1106)	5.5% (779)	5.0% (668)	4.8% (607)
	mTBI	24.3% (1977)	8.6% (699)	7.2% (534)	5.7% (397)	5.3% (347)
	<i>P</i>	<.0001 <sup>b</sup>	.0004 <sup>b</sup>	<.0001 <sup>b</sup>	.0253	.1052
	RR (95% CI)	1.23 (1.15–1.31) <sup>b</sup>	1.20 (1.08–1.32)	1.32 (1.18–1.48)	1.16 (1.02–1.32)	1.12 (0.98–1.28)
Depressive disorders	Comparisons	9.7% (3450)	2.9% (1031)	2.5% (851)	2.3% (781)	2.4% (787)
	mTBI	11.3% (2053)	3.4% (624)	3.0% (533)	2.7% (459)	2.6% (437)
	<i>P</i>	<.0001 <sup>b</sup>	.0027 <sup>b</sup>	.0004 <sup>b</sup>	.0145	.1349
	RR (95% CI)	1.17 (1.10–1.24)	1.17 (1.06–1.29)	1.22 (1.09–1.36)	1.16 (1.03–1.30)	1.09 (0.97–1.23)
0–5 y old	Comparisons	4.3% (187)	0.6% (27)	0.9% (38)	1.6% (67)	1.3% (55)
	mTBI	5.5% (118)	0.8% (18)	1.4% (29)	1.2% (26)	2.2% (45)
	<i>P</i>	.6936	.3933	.8237	.3200	.0835
	RR (95% CI)	1.15 (0.57–2.35)	0.39 (0.05–3.36)	0.83 (0.16–4.29)	1.60 (0.63–4.07)	1.25 (0.97–1.60)
6–9 y old	Comparisons	12.6% (563)	3.6% (162)	3.3% (143)	3.0% (125)	3.3% (133)
	mTBI	14.0% (321)	4.3% (99)	3.3% (73)	4.1% (86)	3.1% (63)
	<i>P</i>	.0835	.6015	.7480	.0937	.3760
	RR (95% CI)	1.25 (0.97–1.60)	1.16 (0.66–2.02)	1.09 (0.64–1.86)	1.51 (0.93–2.46)	1.21 (0.79–1.85)
10–13 y old	Comparisons	18.8% (1746)	5.2% (485)	4.7% (410)	5.0% (421)	5.4% (430)
	mTBI	23.6% (1137)	6.7% (325)	6.7% (300)	6.5% (274)	6.1% (238)
	<i>P</i>	<.0001 <sup>b</sup>	.0004 <sup>b</sup>	.0002 <sup>b</sup>	.0353	.2466
	RR (95% CI)	1.30 (1.18–1.44)	1.43 (1.17–1.74)	1.44 (1.19–1.75)	1.22 (1.01–1.48)	1.12 (0.93–1.35)
14–17 y old	Comparisons	20.7% (3160)	7.2% (1106)	5.5% (779)	5.0% (668)	4.8% (607)
	mTBI	24.3% (1977)	8.6% (699)	7.2% (534)	5.7% (397)	5.3% (347)
	<i>P</i>	.0182	.2007	.0750	.3071	.5823
	RR (95% CI)	1.10 (1.01–1.18)	0.108 (0.96–1.22)	1.13 (0.99–1.30)	1.09 (0.93–1.27)	1.05 (0.88–1.24)
Anxiety disorders	Comparisons	11.8% (4182)	3.4% (1216)	2.9% (981)	3.0% (990)	3.1% (995)
	mTBI	13.2% (2392)	3.8% (681)	3.5% (601)	3.3% (555)	3.4% (555)
	<i>P</i>	<.0001 <sup>b</sup>	.0589	.0003 <sup>b</sup>	.0430	.0450
	RR (95% CI)	1.14 (1.08–1.20)	1.10 (1.00–1.21)	1.21 (1.09–1.34) <sup>b</sup>	1.11 (1.00–1.24)	1.11 (1.00–1.24)
0–5 y old	Comparisons	2.8% (119)	0.4% (19)	0.7% (28)	0.8% (35)	0.9% (37)
	mTBI	3.3% (72)	0.5% (10)	0.8% (18)	1.0% (21)	1.1% (23)
	<i>P</i>	.2033	.8584	.5169	.4797	.3703
	RR (95% CI)	1.21 (0.90–1.64)	1.07 (0.50–2.31)	1.22 (0.67–2.24)	1.22 (0.71–2.10)	1.27 (0.75–2.14)



**TABLE 3** Continued

Psychiatric Diagnoses % (n)	Study Groups	Overall	0–12 mo	13–24 mo	25–36 mo	37–48 mo
6–9 y old	Comparisons	8.0% (371)	2.2% (102)	2.4% (107)	1.9% (86)	1.8% (76)
	mTBI	9.1% (213)	2.9% (69)	2.0% (45)	2.5% (55)	2.0% (44)
	<i>P</i>	.1432	.0607	.3025	.1907	.4667
	RR (95% CI)	1.14 (0.96–1.36)	1.35 (0.99–1.84)	0.83 (0.58–1.18)	1.26 (0.89–1.77)	1.15 (0.79–1.67)
10–13 y old	Comparisons	12.2% (1202)	3.3% (325)	2.8% (267)	3.2% (295)	3.5% (315)
	mTBI	13.8% (689)	3.4% (169)	3.9% (190)	3.5% (163)	3.7% (167)
	<i>P</i>	.0062 <sup>b</sup>	.8192	.0003 <sup>b</sup>	.2753	.4809
	RR (95% CI)	1.15 (1.04–1.28)	1.02 (0.84–1.23)	1.42 (1.18–1.72)	1.11 (0.92–1.36)	1.07 (0.88–1.30)
14–17 y old	Comparisons	14.9% (2490)	4.6% (770)	3.6% (579)	3.7% (574)	3.8% (567)
	mTBI	16.5% (1418)	5.0% (433)	4.3% (348)	4.0% (316)	4.3% (321)
	<i>P</i>	.0009 <sup>b</sup>	.1357	.0137	.2397	.1026
	RR (95% CI)	1.13 (1.05–1.22)	1.10 (0.97–1.24)	1.19 (1.03–1.36)	1.09 (0.94–1.25)	1.12 (0.98–1.29)
Adjustment disorders	Comparisons	6.2% (2275)	1.9% (695)	1.6% (555)	1.5% (521)	1.5% (504)
	mTBI	7.8% (1431)	2.5% (469)	2.0% (361)	1.7% (305)	1.7% (296)
	<i>P</i>	<.0001 <sup>b</sup>	<.0001 <sup>b</sup>	.0001 <sup>b</sup>	.0255	.0209
	RR (95% CI)	1.27 (1.19–1.36)	1.35 (1.20–1.52)	1.30 (1.14–1.49)	1.18 (1.02–1.36)	1.19 (1.03–1.37)
0–5 y old	Comparisons	1.8% (79)	0.2% (8)	0.4% (16)	0.8% (34)	0.5% (21)
	mTBI	2.4% (52)	0.3% (7)	0.6% (12)	0.4% (9)	1.1% (24)
	<i>P</i>	.1034	.2662	.2702	.0919	.0044 <sup>b</sup>
	RR (95% CI)	1.34 (0.94–1.91)	1.78 (0.64–4.92)	1.52 (0.72–3.23)	0.53 (0.25–1.11)	2.35 (1.31–4.24)
6–9 y old	Comparisons	5.8% (268)	1.8% (82)	1.3% (61)	1.2% (54)	1.6% (71)
	mTBI	7.4% (173)	2.1% (49)	1.6% (37)	2.0% (45)	1.9% (42)
	<i>P</i>	.0079	.3417	.3339	.0109	.3467
	RR (95% CI)	1.31 (1.07, 1.59)	1.19 (0.83, 1.70)	1.22 (0.81, 1.85)	1.68 (1.13, 2.50)	1.20 (0.82, 1.77)
10–13 y old	Comparisons	7.2% (722)	2.0% (204)	1.8% (179)	1.8% (170)	1.8% (169)
	mTBI	9.6% (491)	2.9% (147)	2.4% (118)	2.3% (112)	2.4% (114)
	<i>P</i>	<.0001 <sup>b</sup>	.0007 <sup>b</sup>	.0177	.0188	.0099
	RR (95% CI)	1.39 (1.23–1.57)	1.45 (1.17–1.80)	1.33 (1.05–1.68)	1.33 (1.05–1.70)	1.37 (1.08–1.74)
14–17 y old	Comparisons	6.9% (1206)	2.3% (401)	1.8% (299)	1.6% (263)	1.5% (243)
	mTBI	8.1% (715)	3.0% (266)	2.3% (194)	1.7% (139)	1.4% (116)
	<i>P</i>	.0005 <sup>b</sup>	.0005 <sup>b</sup>	.0060 <sup>b</sup>	.6045	.6710
	RR (95% CI)	1.19 (1.08–1.31)	1.32 (1.13–1.55)	1.29 (1.08–1.55)	1.06 (0.86–1.30)	0.95 (0.76–1.19)

mTBI, mild traumatic brain injury; RR, relative risk.

<sup>a</sup> Adjusted relative risk estimates were generated using generalized linear models with logit link function for fixed-interval, interval-censored data, controlled for age, sex, race/ethnicity, low-income residence, and electronic health record transition period. Bonferroni correction resulted in a significance threshold of 2-sided  $P < .00625$ .

<sup>b</sup> Statistically significant risk ratios.

Considering recent findings documenting an increasing rate of mTBI in the pediatric population,<sup>24</sup> our study demonstrates that children who have sustained an mTBI can benefit from initial and ongoing assessment for affective and behavioral disorders. Specifically, these assessments should be prioritized for 10- to 17-year-old children during the first 2 years after injury. Regarding behavioral disorders, these assessments should ideally be conducted up to 4 years after injury and be focused on the 10- to 13-year-old subgroup. Our findings replicate a previous study on affective disorders after mTBI in adults.<sup>25</sup> Across the age span from infants to older adults, the risk of having affective disorders after mTBI is greatest during the first 2 years postinjury. In

children, behavioral disorders are an additional risk. Identifying and treating these mental health disorders could reduce the impact and burden associated with the multifactorial challenges of mTBI. These findings show that mTBI may have a pronounced mental health impact on middle- and high school-aged children. This may be due to increased social and academic demands compared with elementary school-aged children. In addition, other unexplored social factors may further explain these findings, especially underlying factors of socioeconomic vulnerability,<sup>10,11,26,27</sup> such as lower levels of parental education, lower household income, and health insurance coverage.<sup>28,29</sup>

Despite the study's design, several potential limitations exist. First, 43% of our initial sample of children

**TABLE 4** Incidence and Adjusted Risk<sup>a</sup> of Behavioral Disorders During 4 Years After mTBI Versus Comparisons

Psychiatric Diagnoses % (n)	Study Groups	Overall	0–12 mo	13–24 mo	25–36 mo	37–48 mo
Any behavioral disorders	Comparisons	6.7% (2277)	2.7% (921)	1.7% (551)	1.3% (440)	1.1% (365)
	mTBI	7.8% (1377)	2.9% (512)	2.0% (345)	1.6% (265)	1.5% (255)
	<i>P</i>	<.0001 <sup>b</sup>	.2405	.0057 <sup>b</sup>	.0456	.0001 <sup>b</sup>
	RR (95% CI)	1.18 (1.10–1.26)	1.07 (0.96–1.19)	1.21 (1.06–1.39)	1.17 (1.00–1.36)	1.37 (1.17–1.61)
0–5 y old	Comparisons	4.5% (192)	0.7% (30)	0.8% (35)	1.3% (56)	1.7% (71)
	mTBI	5.5% (119)	0.8% (18)	1.1% (24)	1.5% (32)	2.2% (45)
	<i>P</i>	.0436	.5092	.2088	.4814	.1657
	RR (95% CI)	1.28 (1.01–1.62)	1.22 (0.68–2.19)	1.40 (0.83–2.36)	1.17 (0.75–1.81)	1.31 (0.89–1.91)
6–9 y old	Comparisons	9.1% (394)	3.8% (164)	2.7% (111)	1.7% (67)	1.3% (52)
	mTBI	10.1% (228)	4.0% (89)	2.0% (44)	2.6% (56)	1.9% (39)
	<i>P</i>	.2385	.8994	.1186	.0124	.0849
	RR (95% CI)	1.11 (0.93–1.32)	1.02 (0.78–1.32)	0.75 (0.53–1.07)	1.58 (1.10–2.27)	1.45 (0.95–2.20)
10–13 y old	Comparisons	7.7% (703)	2.8% (258)	2.0% (173)	1.7% (151)	1.4% (121)
	mTBI	10.0% (480)	3.7% (179)	2.9% (136)	1.8% (80)	1.9% (85)
	<i>P</i>	<.0001 <sup>b</sup>	.0058 <sup>b</sup>	.0004 <sup>b</sup>	.8811	.0302
	RR (95% CI)	1.32 (1.17–1.49)	1.31 (1.08–1.60)	1.50 (1.20–1.89)	1.02 (0.78–1.34)	1.36 (1.03–1.80)
14–17 y old	Comparisons	6.0% (988)	2.9% (469)	1.4% (232)	1.1% (166)	0.8% (121)
	mTBI	6.5% (550)	2.7% (226)	1.7% (141)	1.2% (97)	1.1% (86)
	<i>P</i>	.1124	.4361	.1126	.3088	.0204
	RR (95% CI)	1.09 (0.98–1.22)	0.94 (0.80–1.10)	1.19 (0.96–1.46)	1.14 (0.88–1.47)	1.39 (1.05–1.83)
Conduct disorder	Comparisons	1.7% (644)	0.6% (233)	0.5% (172)	0.4% (133)	0.3% (106)
	mTBI	2.2% (418)	0.8% (155)	0.6% (107)	0.5% (84)	0.4% (72)
	<i>P</i>	<.0001 <sup>b</sup>	.0060 <sup>b</sup>	.0773	.0775	.0419
	RR (95% CI)	1.31 (1.15–1.48)	1.33 (1.09–1.63)	1.24 (0.98–1.58)	1.28 (0.97–1.68)	1.37 (1.01–1.84)
0–5 y old	Comparisons	1.3% (57)	0.3% (14)	0.4% (15)	0.3% (12)	0.4% (16)
	mTBI	1.5% (33)	0.5% (10)	0.3% (7)	0.5% (11)	0.2% (5)
	<i>P</i>	.4471	.3608	.9191	.1359	.3871
	RR (95% CI)	1.18 (0.77–1.82)	1.46 (0.65–3.30)	0.95 (0.39–2.35)	1.87 (0.82–4.24)	0.64 (0.23–1.75)
6–9 y old	Comparisons	2.4% (113)	0.7% (32)	0.7% (34)	0.6% (26)	0.5% (21)
	mTBI	2.4% (58)	1.1% (26)	0.4% (9)	0.4% (9)	0.6% (14)
	<i>P</i>	.8784	.0679	.0963	.3304	.4011
	RR (95% CI)	1.02 (0.74–1.41)	1.62 (0.96–2.74)	0.53 (0.26–1.12)	0.68 (0.32–1.47)	1.34 (0.68–2.64)
10–13 y old	Comparisons	2.1% (216)	0.7% (69)	0.6% (57)	0.4% (44)	0.5% (46)
	mTBI	3.4% (175)	1.0% (50)	1.0% (50)	0.9% (46)	0.6% (29)
	<i>P</i>	<.0001 <sup>b</sup>	.0495	.0040 <sup>b</sup>	.0003 <sup>b</sup>	.3232
	RR (95% CI)	1.64 (1.34–2.01)	1.44 (1.00–2.08)	1.75 (1.20–2.57)	2.17 (1.43–3.29)	1.26 (0.79–2.02)
14–17 y old	Comparisons	1.4% (258)	0.7% (118)	0.4% (66)	0.3% (51)	0.1% (23)
	mTBI	1.7% (152)	0.8% (69)	0.5% (41)	0.2% (18)	0.3% (24)
	<i>P</i>	.1112	.3032	.2889	.2081	.0116
	RR (95% CI)	1.18 (0.96–1.44)	1.17 (0.87–1.58)	1.23 (0.83–1.83)	0.71 (0.41–1.21)	2.09 (1.18–3.71)
Oppositional defiant disorder	Comparisons	1.8% (668)	0.8% (283)	0.4% (163)	0.4% (131)	0.3% (91)
	mTBI	2.0% (373)	0.7% (123)	0.6% (107)	0.4% (82)	0.3% (61)
	<i>P</i>	.0923	.1818	.0320	.1172	.0630
	RR (95% CI)	1.11 (0.98–1.27)	0.86 (0.70–1.07)	1.31 (1.02–1.67)	1.25 (0.95–1.65)	1.36 (0.98–1.89)
0–5 y old	Comparisons	0.8% (34)	0.2% (7)	0.2% (7)	0.2% (7)	0.3% (13)
	mTBI	0.7% (16)	0.1% (2)	0.1% (3)	0.2% (4)	0.3% (7)
	<i>P</i>	.8824	.4905	.8133	.7953	.8286
	RR (95% CI)	0.95 (0.52–1.74)	0.57 (0.11–2.77)	0.85 (0.22–3.29)	1.18 (0.34–4.03)	1.11 (0.44–2.78)

**TABLE 4** Continued

Psychiatric Diagnoses % (n)	Study Groups	Overall	0–12 mo	13–24 mo	25–36 mo	37–48 mo
6–9 y old	Comparisons	2.6% (122)	0.9% (44)	0.6% (30)	0.5% (25)	0.5% (23)
	mTBI	3.0% (71)	0.8% (19)	0.6% (14)	0.9% (22)	0.7% (16)
	<i>P</i>	.3044	.5603	.8377	.0525	.2902
	RR (95% CI)	1.17 (0.87–1.57)	0.85 (0.49–1.46)	0.93 (0.49–1.77)	1.77 (0.99–3.15)	1.41 (0.74–2.69)
10–13 y old	Comparisons	2.6% (269)	0.9% (91)	0.7% (69)	0.6% (63)	0.5% (46)
	mTBI	3.5% (179)	1.0% (51)	1.1% (57)	0.8% (38)	0.7% (33)
	<i>P</i>	.0030 <sup>b</sup>	.5358	.0053 <sup>b</sup>	.3738	.0947
	RR (95% CI)	1.34 (1.10–1.62)	1.11 (0.79–1.57)	1.65 (1.16–2.35)	1.20 (0.80–1.80)	1.47 (0.93–2.30)
14–17 y old	Comparisons	1.4% (243)	0.8% (141)	0.3% (57)	0.2% (36)	0.1% (9)
	mTBI	1.2% (107)	0.6% (51)	0.4% (33)	0.2% (18)	0.1% (5)
	<i>P</i>	.2524	.0463	.5379	.9668	.8645
	RR (95% CI)	0.87 (0.69–1.10)	0.72 (0.52–0.99)	1.14 (0.74–1.76)	0.99 (0.56–1.74)	1.10 (0.37–3.28)
Attention-deficit/hyperactivity disorder	Comparisons	5.2% (1812)	2.0% (705)	1.3% (456)	1.1% (350)	0.9% (301)
	mTBI	6.1% (1089)	2.2% (394)	1.6% (275)	1.2% (206)	1.3% (214)
	<i>P</i>	<.0001 <sup>b</sup>	.2524	.0451	.1421	.0002 <sup>b</sup>
	RR (95% CI)	1.17 (1.08–1.27)	1.07 (0.95–1.22)	1.17 (1.00–1.36)	1.14 (0.96–1.35)	1.40 (1.17–1.66)
0–5 y old	Comparisons	3.6% (154)	0.4% (17)	0.6% (24)	1.2% (50)	1.5% (63)
	mTBI	4.7% (101)	0.5% (10)	1.0% (21)	1.0% (22)	2.3% (48)
	<i>P</i>	.0222	.6656	.0553	.6775	.0195
	RR (95% CI)	1.35 (1.04–1.75)	1.19 (0.54–2.60)	1.78 (0.99–3.21)	0.90 (0.54–1.49)	1.57 (1.07–2.30)
6–9 y old	Comparisons	7.8% (340)	3.2% (139)	2.4% (101)	1.4% (58)	1.0% (42)
	mTBI	8.3% (188)	3.1% (71)	2.0% (43)	2.0% (43)	1.5% (31)
	<i>P</i>	.5737	.8018	.2487	.1049	.1521
	RR (95% CI)	1.05 (0.87–1.27)	0.96 (0.72–1.29)	0.81 (0.56–1.16)	1.39 (0.93–2.07)	1.41 (0.88–2.25)
10–13 y old	Comparisons	5.9% (547)	2.2% (207)	1.6% (142)	1.2% (109)	1.0% (89)
	mTBI	7.5% (363)	2.9% (142)	2.1% (99)	1.2% (56)	1.5% (66)
	<i>P</i>	.0006 <sup>b</sup>	.0174	.0308	.9073	.0284
	RR (95% CI)	1.27 (1.11–1.46)	1.30 (1.05–1.62)	1.33 (1.03–1.72)	0.98 (0.71–1.36)	1.43 (1.04–1.97)
14–17 y old	Comparisons	4.6% (771)	2.1% (342)	1.2% (189)	0.8% (133)	0.7% (107)
	mTBI	5.1% (437)	2.0% (171)	1.3% (112)	1.0% (85)	0.9% (69)
	<i>P</i>	.0764	.8120	.2099	.1104	.1281
	RR (95% CI)	1.11 (0.99–1.23)	0.98 (0.81–1.18)	1.16 (0.92–1.47)	1.25 (0.95–1.64)	1.27 (0.93–1.72)

mTBI, mild traumatic brain injury; RR, relative risk.  
<sup>a</sup> Adjusted relative risk estimates were generated using generalized linear models with logit link function for fixed-interval, interval-censored data, controlled for age, sex, race/ethnicity, low-income residence, and EHR transition period. Bonferroni correction resulted in a significance threshold of 2-sided *P* < .00625.  
<sup>b</sup> Statistically significant risk ratios.

with mTBIs was excluded for various factors (eg, lapses in health plan coverage and/or the child was initially seen outside the integrated health care system). This may have biased our findings by potentially underestimating how affective and behavioral disorders may be reflected in uninsured children. Second, our requirement to have a diagnosis of mTBI documented in the EHR did not include children who did not seek care for their mTBI, who might have sought care outside our health care system, or who had symptomatology not reaching a threshold for diagnosis of a disorder. Those

patients' diagnostic profiles, outcomes, and other injury-related characteristics may be different than our sample because of variations in clinical practice and limited access to mental health services. Third, we did not investigate the additional impact of multiple mTBIs<sup>30</sup> because preliminary review of our database indicated that this subset was too small relative to the index mTBI cohort. Finally, funding limitations did not permit further exploration of treatment, medication use, and other factors of interest that may have added explanatory variables to our study.

## CONCLUSIONS

Sustaining mTBI significantly increased the risk of having a new affective or behavioral disorder up to 4 years after injury, especially among those who sustained mTBI when aged 10 to 13 years. Initial and ongoing screening for affective and behavior disorders after mTBI in children and adolescents can identify persistent conditions that may pose barriers to recovery.<sup>17</sup>

## ABBREVIATIONS

ADHD: attention deficit hyperactivity disorder  
ED: emergency department  
EHR: electronic health record  
ICD-9-CM: International Classification of Disease, Ninth Revision, Clinical Modification  
mTBI: mild traumatic brain injury  
ODD: oppositional defiant disorder  
TBI: traumatic brain injury

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