

Associations of Lifetime Traumatic Brain Injury Characteristics With Prospective Suicide Attempt Among Deployed US Army Soldiers

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Objective: To estimate associations of lifetime traumatic brain injury (TBI) characteristics with prospective suicide attempt among US Army soldiers. **Method:** The Army STARRS (Study to Assess Risk and Resilience in Servicemembers) Pre/Post Deployment Study surveyed 3 Brigade Combat Teams that were deployed to Afghanistan in 2012. Lifetime TBI and past-month postconcussive/post-TBI symptoms were evaluated at predeployment baseline. Recency and number of TBIs were quantified, and TBI severity was classified on the basis of reports of alteration/loss of consciousness and memory lapse. Suicide attempt data came from administrative records and surveys administered after return from deployment. Logistic regression models estimated associations of TBI characteristics with prospective suicide attempt among baseline respondents who were deployed ($n = 7677$), adjusting for other

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risk factors including lifetime mental disorder. **Results:** One hundred three soldiers made a suicide attempt over a median follow-up period of 30 months (weighted prevalence = 1.31% [0.14%]). In the final model estimating joint associations of TBI severity/recency and past-month postconcussive/post-TBI symptoms, only postconcussive/post-TBI symptoms were associated with a higher risk of suicide attempt (per standard score increase: AOR [adjusted odds ratio] = 1.31; 95% CI, 1.05-1.63; $P = .012$). **Conclusions:** Among the lifetime TBI characteristics evaluated at predeployment baseline, only past-month postconcussive/post-TBI symptoms were prospectively associated with an increased risk of suicide attempt following deployment. Detection of postconcussive/post-TBI symptoms could facilitate targeting of Army suicide prevention programs. **Key words:** *attempted suicide, concussion, military personnel, military psychiatry, postconcussion syndrome, traumatic brain injury*

IDENTIFYING RISK FACTORS for suicidal behaviors is integral to efforts to prevent suicide among members of the US Armed Forces.¹⁻³ Contrary to historical trends,^{4,5} the military suicide rate has equaled or exceeded the adjusted civilian for more than a decade, with a recent report concluding that it remains “high and unchanged from recent years.”⁶ Although research has begun to elucidate factors associated with suicide^{7,8} and nonfatal suicidal behaviors^{9,10} among service members, further investigation is needed to inform military suicide prevention efforts.

Traumatic brain injury (TBI) is a hallmark injury of the Iraq and Afghanistan wars.¹¹ TBI has been linked to suicide among civilians,¹²⁻¹⁴ active-duty military personnel,¹⁵ and veterans,¹⁶ though not all studies find an association.¹⁷ The most comprehensive study of active-duty US service members to date examined risk factors for suicide among more than 100 000 male Marines.¹⁵ Diagnosis of TBI during service was associated with a 4-fold increase in risk of suicide, controlling for other risk factors such as depression and posttraumatic stress disorder (PTSD).

Nonfatal suicidal behaviors can be precursors to suicide death, yet risk factors for the two may differ.^{2,18} Few investigations have examined TBI in relation to risk of nonfatal suicidal behaviors among service members. However, one study found that veterans with a medically documented TBI diagnosis were 3.8 times as likely to attempt suicide as those without a TBI diagnosis.¹⁹ Adjustment for mental disorders attenuated the association, yet TBI remained associated with a 25% increased risk of suicide attempt during the follow-up period.

No prospective study has examined TBI in relation to suicidal behaviors of active-duty service members. Within this population, mental health during and after deployment is of particular concern.²⁰⁻²³ Deployment involves a disruption of routine and of access to protective resources (eg, family support), as well as potential trauma exposure, each of which may increase vulnerability to mental health problems. Redeployment to the United States also carries substantial adjustment demands.²⁴ The identification of predeployment risk factors for postdeployment suicidal behavior can inform

the military’s surveillance and prevention efforts, as well as determine targets for clinical intervention.

The present study evaluates associations of lifetime TBI characteristics with risk of suicide attempt following deployment, using data from the Pre/Post Deployment Study (PPDS) of the Army Study to Assess Risk and Resilience in Servicemembers (Army STARRS).²⁵ Although most prior studies have treated TBI as binary, a few have quantified number²⁶ or severity^{16,27,28} of TBIs, with some finding that these characteristics moderated associations of TBI with suicidal behavior or mortality. To our knowledge, no study has considered TBI-related symptomatology in models of risk for prospective suicide attempt.

We used information from the baseline PPDS survey to characterize age of onset, recency, severity, and number of lifetime TBIs, as well as severity of postconcussive/post-TBI symptoms during the month preceding the index deployment. This report summarizes results of an analysis evaluating each of these factors in relation to risk of suicide attempt from the start of deployment through the next 30 months. Models of associations of lifetime TBI characteristics with suicide attempt adjusted for other baseline risk factors, including sociodemographic and Army career correlates of suicide attempt, as well as lifetime mental disorder.

METHODS

Participants and procedures

The PPDS^{25,29} is a multiwave panel survey of members of 3 Brigade Combat Teams (BCTs) that were deployed to Afghanistan in 2012. Baseline (T_0) data were collected 1 to 2 months before the BCTs were deployed to Afghanistan for an average of 10 months. Follow-up data were collected approximately 1 month (T_1), 3 months (T_2), and 9 months after return from deployment (T_3). The T_0 , T_1 , and T_2 surveys were administered in group sessions at soldiers’ home posts. The T_3 survey was administered individually, via phone or the Internet, permitting evaluation both of soldiers who remained in service and of those who had separated from the Army.

Respondents provided written informed consent to participate in the surveys. Consent to link soldiers' survey responses to their Army/Department of Defense (DoD) administrative records also was requested. Study procedures were approved by the Human Subjects Committees of all collaborating institutions involved in the study.

At baseline, 9949 soldiers were present for duty in the 3 BCTs. Among those present, 9488 (95.4%) consented to participate and 8558 (86.0%) completed the T_0 survey and agreed to linkage of responses to their Army/DoD records. Of those, 7742 were deployed to Afghanistan and were thereby eligible for inclusion in this analysis. However, 61 were excluded for being deployed multiple times before T_3 and 4 were excluded for other reasons (service component other than Regular Army [$n = 2$], deploying during baseline [$n = 1$], and lack of administrative records [$n = 1$]). The final sample included 7677 soldiers, of whom 926 completed only the T_2 survey, 820 completed only the T_3 survey, and 5419 completed both the T_2 and T_3 surveys. Among T_3 respondents, 280 had left Army service, with a mean time out of service of 5.4 months (standard error [SE] = 0.2). There were 26 deaths in the sample, 3 of which were suicides.

Analyses incorporated weights that included propensity-based adjustment for T_0 attrition due to incomplete surveys and inability to link to administrative data (eg, due to the absence of soldier consent). Final values of these weights were poststratified to known demographic and Army service characteristics of soldiers in the 3 BCTs that were deployed to Afghanistan after the T_0 interview dates. Additional details about PPDS design,²⁹ procedures,³⁰ and weighting factors³¹ can be obtained from prior reports.

Measures

Suicide attempt

Soldiers were considered to have had a prospective suicide attempt if they reported any suicide attempt on the PPDS T_2 or T_3 survey. Suicidal behavior was assessed in the T_2 and T_3 surveys using an expanded self-report version of the Columbia Suicide Severity Rating Scale.³² Respondents were asked whether they had ever made a suicide attempt (*purposefully hurting yourself with at least some intention to die*) at any time during their recent deployment or at any time since returning from their recent deployment.

Soldiers also were considered to have had a prospective suicide attempt if Army/DoD administrative records indicated that any attempt had occurred subsequent to their T_0 survey date. Administrative data sources included (1) records from the Department of Defense Suicide Event Report (DoDSER) and the Army

Suicide Event Report (ASER); and (2) ICD-9 (*International Classification of Diseases, Ninth Revision*) codes from Military Health System Data Repository (MDR), Theater Medical Data Store (TMDS), and TRANSCOM (Transportation Command) Regulating and Command and Control Evacuating System (TRAC2ES). Among T_0 survey respondents, time to T_3 ranged from 16 to 30 months (median = 21 months). To align with the PPDS follow-up period, administrative records for up to 30 months following the start of the index deployment were considered. Median number of months of records available for a given soldier was 30 months (interquartile range [IQR] = 0; range, 2-30 months), corresponding to a total of 221 234 person-months for the 7677 soldiers in the sample.

Traumatic brain injury

PPDS T_0 survey assessment of TBI began with the following probe: *How many times in your life (including childhood and adulthood) did you have a head, neck, or blast injury that . . .* followed by descriptions of alteration of consciousness (AOC; *didn't knock you out but caused you to be dazed or "see stars"*), loss of consciousness (LOC; *knocked you out*), and posttraumatic amnesia (PTA; *caused you to have a lapse in memory of events before, during, or after the injury*). Soldiers indicated how many times they had sustained TBIs with AOC, LOC for less than 30 minutes, LOC for 30 minutes to 24 hours, LOC for more than 24 hours, PTA for less than 30 minutes, PTA for 30 minutes to 24 hours, and PTA for more than 24 hours. Causes of each lifetime injury were not queried in the survey; thus, information was not available regarding whether TBI(s) had occurred during the course of Army service (eg, during previous deployments).

"Probable very mild TBI" was defined as endorsing a head, neck, or blast injury with AOC-only. "Probable mild TBI" was defined as endorsing a head, neck, or blast injury with LOC for up to 30 minutes and/or PTA for up to 30 minutes. "Probable moderate-to-severe TBI" was defined as endorsing a head, neck, or blast injury with LOC for 30 minutes or more and/or PTA lasting 30 minutes or more. Application of these criteria entailed that TBIs classified as very mild or mild aligned with standard definitions of mild TBI; most TBIs classified as moderate-to-severe would fall into higher clinical severity categories. In addition to the number and probable severity of lifetime TBIs, the T_0 survey assessed how recently respondents had experienced TBIs with AOC-only, LOC, and PTA (*past 30 days, 1-6 months ago, 7-12 months ago, 1-2 years ago, 3-5 years ago, 6 or more years ago*) and ages at which the first TBIs with AOC-only, LOC, and PTA had occurred.

Postconcussive/post-TBI symptoms

A prior report described derivation of an 8-item Post-Concussive Symptom Scale (PCS-8)³³ based on T_0 survey items assessing past-month frequency of headaches, light sensitivity, noise sensitivity, dizziness/balance problems, irritability, difficulty concentrating, memory problems, and feeling tired/easily fatigued (Cronbach $\alpha = 0.88$). PCS-8 scores were standardized for the current analysis.

Other somatic symptoms

To evaluate specificity of associations of postconcussive/post-TBI symptoms with suicide attempt, we derived another score to quantify other somatic symptoms at T_0 . The score was based on exploratory factor analysis (EFA) of the entire pool of 18 items assessing past-month somatic symptoms in the T_0 survey. Results supported a 2-factor model (eigenvalues = 10.1, 1.4), with a dominant first factor defined by sleep problems, pain, muscle tension, restlessness, appetite disturbance, and psychomotor retardation, as well as some symptoms assessed by the PCS-8 (memory problems, difficulty concentrating, irritability, headaches, dizziness, feeling tired, and being easily fatigued). To eliminate overlap with the PCS-8, standardized scores on this factor were regressed onto standardized PCS-8 scores and residual values were used as an index of “other somatic symptoms” at T_0 .

Lifetime mental disorder

Lifetime *DSM-IV* (*Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition) mental disorders were assessed at T_0 using survey items adapted from the Composite International Diagnostic Interview screening scales (CIDI-SC)³⁴ and a 6-item screening version of the PTSD Checklist (PCL).³⁵ The Army STARRS Clinical Reappraisal Study³⁶ found satisfactory concordance between CIDI-SC/modified PCL diagnoses and diagnoses from structured clinical interviews. Disorders assessed included lifetime major depressive disorder, mania/hypomania, generalized anxiety disorder, panic disorder, PTSD, intermittent explosive disorder, conduct disorder, oppositional defiant disorder, and alcohol or other substance use disorder, as well as adult attention-deficit/hyperactivity disorder (which was required to be symptomatic during the preceding 6 months). An analysis that included a wide range of baseline mental health variables indicated that the presence versus absence of any lifetime mental disorder was the most robust predictor of suicide attempt in this sample (data to be presented in a separate report). Thus, all models of associations of TBI characteristics with suicide attempt adjust for any lifetime mental disorder.

Sociodemographic and Army career characteristics

Sociodemographic and Army career correlates of suicide attempt were identified before estimating associations of TBI characteristics with suicide attempt. The sociodemographic variables considered were age, sex, race/ethnicity, education, marital/relationship status, religious preference, and nativity (self and parents). Army career characteristics included years of Army service, rank, rank below expectation, demotion during the past year, Military Occupational Specialty, deployment history, dwell time, and perceived unit cohesion. Table 1 provides categories and definitions of these variables. The unit cohesion score reflects individual perceptions of cohesion and was based on soldiers' ratings of trust and respect among unit members, respect for unit leaders, treatment of unit members by leaders, discrimination, and morale. EFA of these ratings supported a 1-factor model and internal consistency of the items was high (Cronbach $\alpha = 0.89$). An overall unit cohesion score was derived by standardizing each rating, summing all 16 standardized ratings, and standardizing the sum.

Data analysis

Logistic regression was performed to evaluate associations of lifetime TBI variables with prospective suicide attempt. Initial models estimated bivariate associations of lifetime TBI characteristics (age of onset, recency, severity, number) with suicide attempt, controlling for months of administrative data, T_2/T_3 survey completion, sociodemographic and Army career correlates of suicide attempt, and lifetime mental disorder. Subsequent models were fit adjusting for any lifetime TBI to determine which characteristics of TBI history related to risk of suicide attempt after accounting for effects of any TBI exposure. Results of bivariate models informed construction of multivariable models that estimated joint associations of lifetime TBI characteristics with suicide attempt.

PPDS data are clustered (by BCT and administration session) and weighted; therefore, standard errors were generated using the design-based Taylor series linearization method. Design-based Wald χ^2 tests were used to examine multivariate significance. SAS 9.4³⁷ was used to conduct all analyses. Two-tailed $P < .05$ was considered statistically significant.

RESULTS

Table 1 presents the sociodemographic and Army career characteristics of the sample, which was predominantly male, white, and high school educated. Enlisted soldiers comprised the majority, and most had been deployed at least once prior to the index deployment.

TABLE 1 *Distribution and association of sociodemographic and Army career characteristics with any prospective suicide attempt (N = 7677)^a*

	%	SE	Bivariate models ^b		Multivariate model: Demographic variables only		Multivariate model: Demographic and Army career variables	
			OR	95% CI	AOR	95% CI	AOR	95% CI
Age at T ₀ (median, IQR)	25.0	8.3	0.93	0.89-0.98	0.94	0.90-0.98	0.92	0.87-0.97
Sex								
Female	5.1	0.5	1.00	Ref				
Male	94.9	0.5	0.42	0.22-0.79	0.41	0.22-0.76	0.40	0.21-0.77
Race/ethnicity								
White, non-Hispanic	68.0	0.7	1.00	Ref				
Black, non-Hispanic	12.6	0.6	0.89	0.46-1.70				
Hispanic	12.1	0.4	1.38	0.76-2.50				
Other	7.3	0.3	1.03	0.36-2.91				
χ^2_3			1.25	<i>P</i> = .74				
Education								
College graduate or higher	16.2	1.1	1.00	Ref				
Some college	3.2	0.2	0.77	0.07-8.23				
High school or less ^c	80.7	1.1	4.09	1.22-13.76	3.17	1.20-8.41	2.70	1.06-6.91
χ^2_2			8.87	<i>P</i> = .012				
Marital/current relationship status								
Currently married	55.9	0.9	1.00	Ref				
Previously married; currently engaged/in serious relationship	4.4	0.2	1.38	0.53-3.58				
Previously married; not currently engaged/in serious relationship	5.6	0.4	3.08	1.42-6.66	3.51	1.66-7.41	3.17	1.48-6.81
Never married; currently engaged/in serious relationship	14.0	0.5	0.89	0.50-1.61				
Never married; not currently engaged/in serious relationship	20.1	0.7	0.80	0.48-1.36				
χ^2_4			15.44	<i>P</i> = .004				
Religious preference								
Protestant	49.8	0.7	1.00	Ref				
Catholic	21.1	0.5	1.36	0.72-2.56				
Other	4.0	0.2	2.07	0.73-5.87				
None	25.2	0.5	1.73	1.14-2.63	1.45	0.99-2.13		
χ^2_3			7.92	<i>P</i> = .048				
Nativity								
Soldier and 2 parents born in the United States	79.3	0.6	1.00	Ref				
Soldier and 1 parent born in the United States	6.3	0.0	0.89	0.35-2.22				
Soldier and 0 parents born in the United States	4.9	0.2	1.59	0.55-4.61				
Soldier not born in the United States	9.5	0.4	0.93	0.44-1.97				
χ^2_3			1.15	<i>P</i> = .76				
Rank in Army								
Officer	12.8	1.0	1.00	Ref				
E1-E4	46.2	1.5	2.07	0.23-18.27				
E5-E9	41.1	0.7	2.95	0.37-23.75				
χ^2_2			3.21	<i>P</i> = .20				
Rank below expectation	1.9	0.2	1.05	0.29-3.75				
Demoted in past year	1.8	0.2	1.68	0.56-5.10				
Years of Army service (median, IQR)	4.1	6.8	1.02	0.94-1.12				

(continues)

TABLE 1 Distribution and association of sociodemographic and Army career characteristics with any prospective suicide attempt ($N = 7677$)^a (Continued)

	%	SE	Bivariate models ^b		Multivariate model: Demographic variables only		Multivariate model: Demographic and Army career variables	
			OR	95% CI	AOR	95% CI	AOR	95% CI
Military Occupational Specialty								
Combat service support	26.9	1.9	1.00	Ref				
Combat arms	59.2	2.5	1.12	0.55-2.26				
Combat support	13.9	1.0	1.80	0.92-3.51				
χ^2_2			5.96	$P = .051$				
Prior deployment ^d								
No prior deployment	41.6	1.2	1.00	Ref			1.00	Ref
Deployed within the first year of service	11.6	0.4	2.16	1.27-3.68			2.09	1.22-3.56
Deployed, but not in the first year of service	46.8	1.3	1.52	0.92-2.51			1.45	0.90-2.34
χ^2_2			9.36	$P = .009$			8.27	$P = .016$
Short dwell time ^e	32.3	0.7	1.28	0.83-1.98				
Standardized unit cohesion (mean, SD)	0.00	1.00	0.79	0.65-0.96			0.80	0.66-0.97

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; IQR, interquartile range; OR, odds ratio; PPDS, Pre/Post Deployment Study; SE, standard error.

^aThe sample comprised PPDS respondents who completed the predeployment (T_0) survey and were subsequently deployed to Afghanistan. The outcome includes any suicide attempt documented in Army/Department of Defense administrative records or reported in the PPDS T_2 or T_3 surveys. All models control for months in administrative data and T_2/T_3 survey completion. ORs that appear in **bold** are statistically significant ($P < .05$); exact P values are provided for χ^2 tests.

^bBivariate associations of Army career characteristics with suicide attempt are adjusted for sociodemographic correlates of suicide attempt (age, sex, high school or less education, and marital/relationship status of "previously married, not currently engaged/in a serious relationship").

^cIncludes soldiers whose education level was recorded in administrative data as "high school graduate" ($n = 5671$; 70.4% [SE = 1.0%] of the total sample), "GED or equivalent" ($n = 684$; 8.6% [SE = 0.4%] of total sample), and "less than high school" ($n = 154$; 1.7% [SE = 0.2%] of the total sample).

^dNumber of prior deployments also was considered but was not associated with suicide attempt.

^eShort dwell time was defined as "number of months since most recent deployment was less than 2 times the duration of most recent deployment in months."

Within the sample, 103 soldiers had 1 or more suicide attempts during the follow-up period (weighted prevalence = 1.31%; SE = 0.14%). Outcome events by mode of data collection are shown in Supplementary Digital Content Table 1 (available at: <http://links.lww.com/JHTR/A319>). Sociodemographic and Army career characteristics associated with a higher risk of prospective suicide attempt were younger age, female sex, educational attainment of high school or less, being previously married and not currently engaged/in a serious relationship, having deployed within one's first year of service, and lower perceived unit cohesion (see Table 1). Adjusting for those characteristics, lifetime mental disorder was associated with an increased risk of prospective suicide attempt (adjusted odds ratio [AOR] = 2.64; 95% CI, 1.76-3.98; $P < .001$). All subsequent models control for the sociodemographic and Army career correlates of suicide attempt, as well as lifetime mental disorder.

Distribution of lifetime TBI characteristics is summarized in Table 2. Nearly two-thirds of soldiers had sustained TBI during their lifetimes. In approximately half of these cases, the worst TBI was classified as "mild" and in another third of cases, the worst TBI was classified as "very mild." Having sustained a single TBI was the exception rather than the norm, with almost a third of the soldiers who endorsed lifetime TBI reporting 5 or more such injuries (median = 2.4; IQR = 3.9). Most soldiers with lifetime TBI reported that their first TBI occurred during childhood or adolescence (median age of first TBI = 13.7 years; IQR = 6.6).

Bivariate associations of TBI characteristics with prospective suicide attempt

Results of bivariate models of associations of TBI characteristics with suicide attempt appear in Table 2. Odds of suicide attempt did not differ for soldiers

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TABLE 2 *Distribution and association of lifetime TBI characteristics with any prospective suicide attempt^a*

	Prevalence				Association with suicide attempt (N = 7677)			
	Overall		Among those with any lifetime TBI		Adjusting for demographic/Army career correlates of SA and lifetime mental disorder		Adjusting for demographic/Army career correlates of SA, lifetime mental disorder, and any lifetime TBI	
	(N = 7677)		(n = 4808)		AOR	95% CI	AOR	95% CI
	%	SE	%	SE				
Any very mild TBI ^b	50.5	0.7	77.9	0.6	0.72	0.44-1.19		
Any mild TBI ^b	37.8	0.7	58.4	0.8	1.14	0.67-1.96		
Any moderate-to-severe TBI ^b	10.1	0.4	15.7	0.6	1.68	0.85-3.35		
Any lifetime TBI	64.8	0.7	100	...	0.92	0.56-1.52		
Severity of worst lifetime TBI								
Never sustained TBI	35.2	0.7	0.0	...	1.00	Ref	1.00	Ref
Very mild	23.6	0.5	36.4	0.8	0.48	0.25-0.90	1.00	Ref
Mild	31.1	0.7	48.0	0.9	0.97	0.54-1.74	2.02	1.16-3.50
Moderate-to-severe	10.1	0.4	15.7	0.6	1.72	0.86-3.43	3.59	1.64-7.86
$\chi^2_{3/2}$					12.04	P = .007	11.93	P = .003
Age of first TBI (median, IQR)			13.7	6.6			1.01	0.95-1.07
Years since first TBI (median, IQR)			9.5	8.7			0.97	0.92-1.02
Most recent TBI of any severity								
Past 12 mo	17.2	0.6	26.6	0.8	1.17	0.63-2.18	1.80	0.82-3.96
1-2 y ago	13.3	0.5	20.6	0.6	1.01	0.57-1.81	1.57	0.73-3.35
3-5 y ago	14.6	0.5	22.6	0.7	0.77	0.37-1.60	1.18	0.55-2.54
6+ y ago	19.6	0.6	30.2	0.9	0.65	0.31-1.38	1.00	Ref
Never sustained TBI	35.2	0.7			1.00	Ref		
$\chi^2_{4/3}$					2.99	P = .56	2.96	P = .40
Number of TBIs (median, IQR)	1.0	3.3	2.4	3.9				
0	35.2	0.7			1.00	Ref		
1	14.9	0.5	23.0	0.8	0.90	0.44-1.85	1.00	Ref
2	13.7	0.4	21.1	0.6	0.65	0.29-1.42	0.72	0.25-2.05
3-4	15.5	0.5	23.9	0.6	0.78	0.40-1.52	0.86	0.43-1.72
5-7	10.4	0.4	16.0	0.7	1.09	0.49-2.40	1.21	0.61-2.39
8+	10.4	0.4	16.0	0.6	1.32	0.68-2.54	1.46	0.71-3.03
$\chi^2_{5/4}$					4.42	P = .49	4.21	P = .38
Symptom severity at T ₀								
Postconcussive/post-TBI symptoms (mean, SD)	0.0	1.0			1.38	1.09-1.73	1.40	1.12-1.75
Other somatic symptoms (mean, SD)	0.0	0.1			1.12	0.68-1.84	1.12	0.68-1.84

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; IQR, interquartile range; PPDS, Pre/Post Deployment Study; SA, suicide attempt; SE, standard error; TBI, traumatic brain injury.

^aThe analysis sample comprised PPDS respondents who completed the predeployment (T₀) survey and were deployed to Afghanistan. The outcome includes any SA documented in Army/Department of Defense administrative records or reported in the PPDS T₂ or T₃ surveys. All models control for months in administrative data, T₂/T₃ survey completion, sociodemographic and Army career correlates of SA (age, sex, high school or less education, marital/relationship status of "previously married, not currently engaged/in a serious relationship," having deployed within the first year of Army service, and perceived unit cohesion at T₀), and lifetime mental disorder at T₀. AORs that appear in **bold** are statistically significant (P < .05); exact P values are provided for χ^2 tests.

^bModel includes additional adjustment for having had TBI(s) of greater or lesser severity; thus, adjusted odds are relative to no lifetime TBI.

with versus without any lifetime TBI prior to the index deployment. Soldiers with any very mild TBI, any mild TBI, and any moderate-to-severe TBI also did not differ significantly from those with no lifetime TBI in terms of their risk of suicide attempt. However, the severity of the worst lifetime TBI was associated with odds of suicide attempt ($\chi^2 = 12.04$, $P = .007$). Soldiers whose worst lifetime TBI was very mild had a lower risk of suicide attempt than those with no lifetime TBI (AOR = 0.48; 95% CI, 0.25-0.90; $P = .019$). Also, after adjusting for any lifetime TBI, those whose worst TBI was mild (AOR = 2.02; 95% CI, 1.16-3.50; $P = .010$) or moderate-to-severe (AOR = 3.59; 95% CI, 1.64-7.86; $P = .001$) had a higher risk of suicide attempt than those whose worst TBI was very mild.

Bivariate models also showed that severity of postconcussive/post-TBI symptoms was positively related to risk of suicide attempt, adjusting for other risk factors and any lifetime TBI (AOR = 1.40 [per standard score increase]; 95% CI, 1.12-1.75; $P < .001$). In contrast, severity of other somatic symptoms was not associated with suicide attempt. Age of onset, recency, and number of lifetime TBIs also lacked significant associations with the outcome (see Table 2).

To ensure that collapsing across TBI severity did not obscure effects of age of onset, recency, or number of TBIs, we fit additional bivariate models to examine the associations of TBI characteristics within each severity category. None of the characteristics of very mild TBI history were associated with suicide attempt (see Supplementary Digital Content Table 2, available at: <http://links.lww.com/JHTR/A319>). However, recency of mild TBI related to risk of suicide attempt ($\chi^2 = 6.26$, $P = .044$; see Supplementary Table 3, available at: <http://links.lww.com/JHTR/A319>). Adjusting for any mild TBI, having sustained mild TBI within the past year was associated with higher odds of suicide attempt (AOR = 3.41; 95% CI, 1.24-9.35; $P = .014$) than having had mild TBI more than 5 years before T_0 . Odds of suicide attempt also appeared elevated among those who had sustained mild TBI 1 to 5 years before T_0 (AOR = 1.99; 95% CI, 0.87-4.57; $P = .093$), but the difference from those who sustained mild TBI more than 5 years before T_0 was not significant. Models adjusting for any mild TBI revealed no significant differences in risk of suicide attempt based on age of onset or number of mild TBIs. Risk of suicide attempt also did not differ on the basis of age of onset or number of moderate-to-severe TBIs (see Supplementary Digital Content Table 4, available at: <http://links.lww.com/JHTR/A319>). Adjusting for any moderate-to-severe TBI, odds of suicide attempt appeared elevated among soldiers with moderate-to-severe TBI in the past 5 years (AOR = 3.10; 95% CI, 0.63-15.15; $P = .15$) relative to those whose most re-

cent moderate-to-severe TBI occurred more than 5 years ago; however, the between-groups difference was not significant.

Multivariable models of associations of TBI characteristics with prospective suicide attempt

Multivariable models were constructed to further evaluate associations of lifetime TBI characteristics with prospective suicide attempt. On the basis of the bivariate model results, dummy variables were used to categorize TBI history first by the severity of the worst lifetime TBI and then, in the case of mild and moderate-to-severe TBI, by how recently an injury of that severity had occurred. The first multivariable model estimated associations of the TBI history categories with suicide attempt. A subsequent model estimated joint associations of TBI history and PCS-8 score. Mean PCS-8 score by TBI history is shown in Figure 1. Number and weighted prevalence of outcome events by TBI history and PCS-8 score are shown in Table 3.

In multivariable model 1 (see Table 4), TBI history of “very mild only” was associated with a reduced risk of suicide attempt relative to no lifetime TBI (AOR = 0.48; 95% CI, 0.26-0.90; $P = .019$). In addition, the association of moderate-to-severe TBI history with suicide attempt approached significance ($\chi^2 = 5.33$, $P = .070$). Soldiers with moderate-to-severe TBI in the past 5 years exhibited approximately twice the odds of suicide attempt of soldiers with no lifetime TBI (AOR = 2.08; 95% CI, 1.02-4.24; $P = .039$).

Multivariable model 2 included both TBI history and postconcussive/post-TBI symptom severity as predictors (see Table 4). PCS-8 score was positively associated with odds of suicide attempt (AOR = 1.31; 95% CI, 1.05-1.63; $P = .012$), and TBI history of “very mild only” remained associated with reduced risk of suicide attempt compared with no lifetime TBI (AOR = 0.45; 95% CI, 0.24-0.85; $P = .012$). However, soldiers with moderate-to-severe TBI in the past 5 years no longer displayed significantly higher odds of suicide attempt than those with no lifetime TBI. Post-TBI symptoms thus appeared to explain the association of past-5-year moderate-to-severe TBI with prospective suicide attempt. Notably, attenuation of that association was not observed (AOR $_{\Delta}$ = -0.01; see Supplementary Digital Content Table 5, available at: <http://links.lww.com/JHTR/A319>) when the “other somatic symptoms” score was added to multivariable model 1 instead of the PCS-8 score, suggesting that the increased risk of suicide attempt among those with past-5-year moderate-to-severe TBI was mediated by post-TBI symptoms specifically, not somatic symptoms in general. Another model added an interaction term to multivariable model 2 to test whether the association of postconcussive/post-TBI symptoms

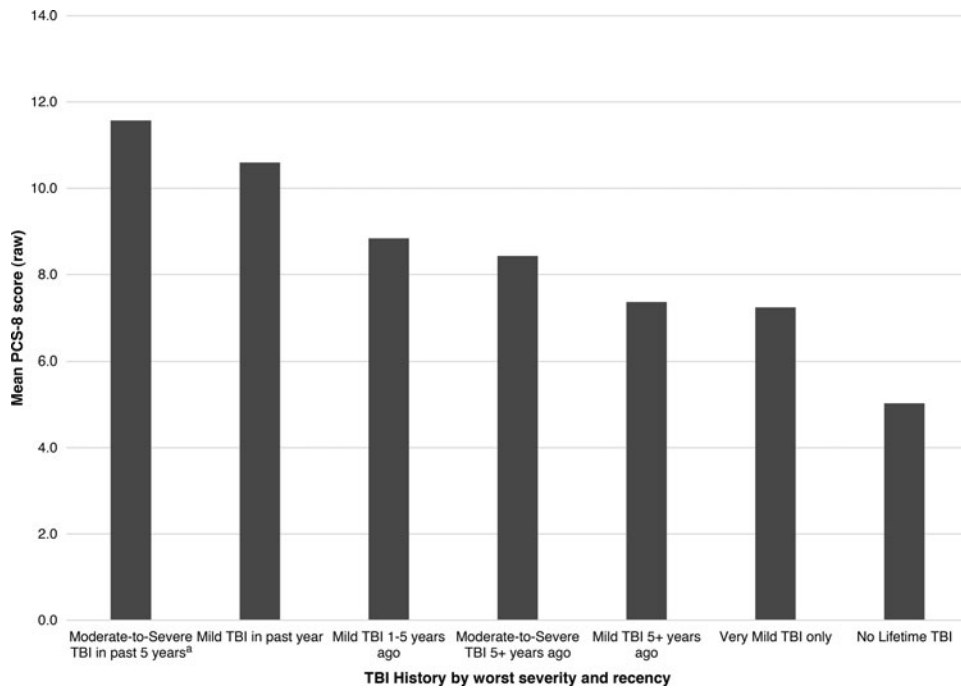


Figure 1. Postconcussive/post-TBI symptom severity by TBI history among PPDS respondents who were deployed to Afghanistan (N = 7677). Both TBI history and past-month postconcussive/post-TBI symptoms were assessed 1 to 2 months prior to the index deployment. ^aFor a subset (n = 435) of soldiers with worst TBI severity of “moderate-to-severe” and any lifetime mild TBI, the survey items did not permit us to distinguish whether the most recent TBI with loss of consciousness and/or memory lapse was mild or moderate-to-severe. Thus, some respondents included in the category “moderate-to-severe TBI in past 5 years” may have had mild TBI(s) in the past 5 years and moderate-to-severe TBI(s) earlier than that. TBI indicates traumatic brain injury; PCS-8, 8-item Post-Concussive Symptom Scale (theoretical range = 0-32).

TABLE 3 *Prospective suicide attempt by TBI history and postconcussive/post-TBI symptom severity*

	Size of subgroup, n (weighted %)	Any prospective suicide attempt within group, n (weighted %)
Overall	7677 (100)	103 (1.31)
TBI history (by worst severity, then recency)		
Moderate-to-severe TBI, within past 5 y ^a	528 (7.1)	20 (3.59)
Moderate-to-severe TBI, 5+ y ago	218 (3.0)	2 (0.83)
Mild TBI, within past year	376 (5.1)	11 (3.19)
Mild TBI, 1-5 y ago	1044 (14.0)	17 (1.59)
Mild TBI, 5+ y ago	876 (12.0)	7 (0.70)
Very mild TBI only	1766 (23.6)	11 (0.57)
No lifetime TBI	2869 (35.2)	35 (1.20)
PCS-8 score ^b		
Lowest quartile	1897 (24.1)	12 (0.57)
Low-mid quartile	1745 (22.2)	20 (1.05)
High-mid quartile	2083 (27.5)	24 (1.06)
Highest quartile	1952 (26.2)	47 (2.46)

Abbreviations: PCS-8, 8-item Post-Concussive Symptom Scale; TBI, traumatic brain injury.

^aFor a subset (n = 435) of respondents with worst TBI severity of “moderate-to-severe” and any lifetime mild TBI, the survey items did not permit us to distinguish whether the most recent TBI with loss of consciousness and/or memory lapse was mild or moderate-to-severe. Thus, some respondents included in this category may have had mild TBI(s) in the past 5 years and moderate-to-severe TBI(s) earlier than that.

^bAlthough quartiles are presented in this table, the continuous PCS-8 score was used in all regression models.

TABLE 4 Associations of TBI history and postconcussive/post-TBI symptoms with prospective suicide attempt ($N = 7677$)^a

	Association with any prospective suicide attempt			
	Multivariable model 1		Multivariable model 2	
	AOR	95% CI	AOR	95% CI
TBI history (by worst severity, then recency)				
Moderate-to-severe TBI				
Most recent within past 5 y ^b	2.08	(1.02-4.24)	1.72	(0.86-3.45)
Most recent 5+ y ago	0.66	(0.14-3.26)	0.63	(0.13-2.99)
χ^2_2	5.33	$P = .07$	3.15	$P = .21$
Mild TBI				
Most recent within past year	1.80	(0.74-4.35)	1.54	(0.63-3.78)
Most recent 1-5 y ago	0.99	(0.47-1.82)	0.81	(0.41-1.61)
Most recent 5+ y ago	0.58	(0.25-1.31)	0.55	(0.24-1.26)
χ^2_3	4.88	$P = .18$	4.77	$P = .19$
Very mild TBI only	0.48	(0.26-0.90)	0.45	(0.24-0.85)
No lifetime TBI	1.00	Ref	1.00	Ref
Symptom severity at T_0				
Postconcussive/post-TBI symptoms (mean, SD)			1.31	(1.05-1.63)

Abbreviation: AOR, adjusted odds ratio; CI, confidence interval; PPDS, Pre/Post Deployment Study; TBI, traumatic brain injury.

^aThe sample comprised PPDS respondents who completed the predeployment (T_0) survey and were deployed to Afghanistan. The outcome includes any suicide attempt documented in Army administrative data or reported in the PPDS T_2 or T_3 surveys. All models control for months in administrative data, T_2/T_3 survey completion, sociodemographic and Army career correlates of suicide attempt (age, sex, high school or less education, marital/relationship status of "previously married, not currently engaged/in a serious relationship," having deployed within the first year of Army service, and perceived unit cohesion at T_0), and lifetime mental disorder at T_0 . AORs that appear in **bold** are statistically significant ($P < .05$); exact P values are provided for χ^2 tests.

^bFor a subset ($n = 435$) of respondents with worst TBI severity of "moderate-to-severe" and any lifetime mild TBI, the survey items did not permit us to distinguish whether the most recent TBI with loss of consciousness and/or memory lapse was mild or moderate-to-severe. Thus, some respondents included in this category may have had mild TBI(s) in the past 5 years and moderate-to-severe TBI(s) earlier than that.

with suicide attempt was moderated by TBI history, but the PCS-8 \times TBI history interaction was nonsignificant ($\chi^2_6 = 5.94$, $P = .43$). Thus, multivariable model 2 was accepted as the final model.

DISCUSSION

This study is the first to prospectively evaluate associations of lifetime TBI characteristics with suicide attempt following military deployment and the first to consider postconcussive/post-TBI symptoms as a risk factor for suicidal behavior. Amid a range of current and historical TBI characteristics assessed in the predeployment survey, only past-month postconcussive/post-TBI symptoms were associated with an increased risk of prospective suicide attempt. This association was observed in the presence of controls for lifetime mental disorder and sociodemographic/Army career correlates of suicide attempt.

The current results imply that detection of postconcussive/post-TBI symptoms could help identify at-risk soldiers and thus facilitate targeting of Army suicide prevention programs. Surveillance of

these symptoms would also yield opportunities for treatment³⁸ of distressing and disabling symptoms before soldiers are deployed. In terms of research implications, our findings highlight the need for investigation of potential mechanisms underlying the association between postconcussive/post-TBI symptoms and suicide attempt. If evidence of a causal relationship were to emerge (eg, through intervention studies), postconcussive/post-TBI symptoms could be targeted within suicide prevention programs.

An unexpected finding was that soldiers with "very mild TBI only" had decreased odds of suicide attempt relative to soldiers with no lifetime TBI. A history of very mild TBI could indicate greater involvement in sports or vigorous physical activity, which are inversely associated with hopelessness and suicidal behavior among adolescents.³⁹⁻⁴¹ Whether this relates to the observed protective effect of very mild TBI is unknown and suggests another area for future investigation.

The seemingly elevated risk of suicide attempt among soldiers who had sustained moderate-to-severe TBI within 5 years of the index deployment was largely explained by post-TBI symptoms. Evidence from the

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analysis further suggested that this association was mediated by post-TBI symptoms specifically, as opposed to somatic symptoms in general. While this provides indirect evidence of a link between TBI and the symptoms assessed by the PCS-8, we acknowledge that such symptoms can also result from other medical conditions and mental disorders. TBI history did not interact with PCS-8 score to predict suicide attempt, suggesting that for the purpose of suicide risk assessment, screening can focus primarily on the severity of recent postconcussive/post-TBI symptoms (as opposed to the specifics of TBI history). However, future studies should continue to investigate possible interaction effects of TBI history and postconcussive/post-TBI symptoms on risk of suicide attempt, as our study may not have been adequately powered to detect significant interactions.

Approximately 1.3% of soldiers made a suicide attempt over an average follow-up period of 30 months, according to their own report or administrative records. The 2014 National Survey on Drug Use and Health found that the past-year prevalence of suicide attempt among US adults was 0.5% overall and 1.2% among young adults (aged 18–25 years).⁴² The past-year prevalence of suicide attempt among male young adults (who were well represented in the PPDS sample) was 1.0%. Although they provide context for the findings of our study, these general population estimates cannot be directly compared with the rate of suicide attempt observed in the PPDS sample, due to differences in time frame of suicide attempt assessment, sample characteristics, and other study methodology.

The relatively low concordance of self-report and administrative suicide attempt data was not unexpected. Other investigators⁴³ have noted discrepancies between suicide attempt data originating from different sources (eg, clinical interviews vs medical records). In our study, asynchronies in the duration of administrative versus survey follow-up were one possible source of discrepancy. Suicide attempts that occurred after separation from Army service would not appear in administrative records, and administratively documented attempts that occurred after soldiers completed T_3 assessment would not be captured via self-report. We also expected some self-reported attempts to be absent from Army/DoD records, as medical or mental health services are not sought in all cases of suicide attempt. Some administratively documented suicide attempts may not have been disclosed on surveys due to fear of adverse consequences or stigma.

Our results must be considered alongside several limitations. Retrospective self-report data are vulnerable to response and recall biases. With respect to TBI assessment, very mild TBIs might not be remembered or considered important enough to report, resulting in underestimation of the occurrence or number of TBIs. Severity of TBIs also might be misjudged if respondents

did not accurately remember how long periods of LOC or PTA had lasted. While we acknowledge the limitations inherent in self-assessment, more lifetime injuries are likely to be captured with this mode of assessment than with reliance on medical record data.⁴⁴

The baseline PPDS survey did not collect information about circumstances surrounding each TBI; thus, we were unable to estimate the proportion of lifetime TBIs that occurred during previous deployments/Army service. In addition, we sought to identify risk factors for suicide attempt that could be detected *before* soldiers were deployed; consequently, the analysis did not consider the effects of TBI(s) sustained during or after return from the index deployment. These are important topics for future investigation.

A final limitation of the TBI assessment was that items evaluating age of onset and recency of TBI with LOC and PTA did not contain duration specifiers. Thus, for some cases in which both mild TBI and moderate-to-severe TBI were reported, we could not determine whether the injury of reference for the age of onset and recency questions was mild or moderate-to-severe. The main impact was that, in the final model, we may have overestimated the prevalence of moderate-to-severe TBI in the past 5 years (ie, some of those injuries could have been mild TBIs, and the soldier's moderate-to-severe TBI(s) could have occurred earlier). The PPDS survey items otherwise provided a very high degree of granularity with respect to characterization of respondents' TBI histories.

It is conceivable that soldiers who sustained more severe injuries during the index deployment (including TBIs) were less likely to complete the T_2 and T_3 surveys. Concerns about underrepresentation of this subgroup in the analysis are partly mitigated by the availability of another source of suicide attempt outcome data (ie, Army/DoD administrative records). Finally, suicide attempt and suicide death have different base rates and correlates.^{2,18} Thus, while identifying risk factors for suicide attempt is important, it does not necessarily advance an understanding of suicide death among service members. Future studies should investigate postconcussive/post-TBI symptoms as a potential risk factor for suicide mortality.

In conclusion, predeployment postconcussive/post-TBI symptoms were associated with an increased risk of suicide attempt among soldiers who were deployed to Afghanistan. Detection of postconcussive/post-TBI symptoms may facilitate both targeting of suicide prevention programs and timely intervention to alleviate potentially distressing and disabling symptoms. Future research should investigate mechanisms underlying the association of postconcussive/post-TBI symptoms with suicide attempt, as well as effects of treatment of these symptoms on the mental health outcomes of deployed service members.

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