

Original Investigation

Repetitive Traumatic Brain Injury, Psychological Symptoms, and Suicide Risk in a Clinical Sample of Deployed Military Personnel

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IMPORTANCE Traumatic brain injury (TBI) is believed to be one factor contributing to rising suicide rates among military personnel and veterans. This study investigated the association of cumulative TBIs with suicide risk in a clinical sample of deployed military personnel referred for a TBI evaluation.

OBJECTIVE To determine whether suicide risk is more frequent and heightened among military personnel with multiple lifetime TBIs than among those with no TBIs or a single TBI.

DESIGN Patients completed standardized self-report measures of depression, posttraumatic stress disorder (PTSD), and suicidal thoughts and behaviors; clinical interview; and physical examination. Group comparisons of symptom scores according to number of lifetime TBIs were made, and generalized regression analyses were used to determine the association of cumulative TBIs with suicide risk.

PARTICIPANTS Patients included 161 military personnel referred for evaluation and treatment of suspected head injury at a military hospital's TBI clinic in Iraq.

MAIN OUTCOMES AND MEASURES Behavioral Health Measure depression subscale, PTSD Checklist–Military Version, concussion symptoms, and Suicide Behaviors Questionnaire–Revised.

RESULTS Depression, PTSD, and TBI symptom severity significantly increased with the number of TBIs. An increased incidence of lifetime suicidal thoughts or behaviors was associated with the number of TBIs (no TBIs, 0%; single TBI, 6.9%; and multiple TBIs, 21.7%; $P = .009$), as was suicidal ideation within the past year (0%, 3.4%, and 12.0%, respectively; $P = .04$). The number of TBIs was associated with greater suicide risk (β [SE] = .214 [.098]; $P = .03$) when the effects of depression, PTSD, and TBI symptom severity were controlled for. A significant interaction between depression and cumulative TBIs was also found ($\beta = .580$ [.283]; $P = .04$).

CONCLUSIONS AND RELEVANCE Suicide risk is higher among military personnel with more lifetime TBIs, even after controlling for clinical symptom severity. Results suggest that multiple TBIs, which are common among military personnel, may contribute to increased risk for suicide.

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Suicide is currently the second leading cause of death among military personnel.¹ Since the initiation of combat operations in Afghanistan and Iraq, the suicide rate among US military personnel has steadily risen, with a particularly sharp increase in the Army.¹ Contributing to this heightened suicide risk is the concurrent rise in psychiatric illness among military personnel, especially among those exposed to combat operations. The risk of posttraumatic stress disorder (PTSD), depression, and substance abuse is considerably increased¹⁻³ among military personnel, with each being known risk factors for suicidal behaviors.

Traumatic brain injury (TBI) also has been found to be associated with significantly increased risk for suicidal ideation, suicide attempts, and death by suicide,⁴⁻⁷ especially when occurring together with psychiatric and/or substance abuse problems.⁶⁻⁸ Traumatic brain injury is of particular concern among military personnel owing to increased risk of exposure to concussive injuries resulting from explosions or other military training- and combat-related factors (eg, motor vehicle crashes and falls). Considered a “signature injury” of the Iraq and Afghanistan conflicts, the prevalence of TBI is estimated to be about 8% to 20% in military personnel deployed to one of these locations, with mild (vs moderate or severe) TBI accounting for the vast majority of cases.² Among veterans who have received treatment from the Department of Veterans Affairs,⁹ a diagnosis of TBI is associated with increased risk for death by suicide, although this same risk has not been found among active military personnel.¹⁰

Recent studies with Iraq and Afghanistan veterans have provided support for the role of psychological factors, such as depression and PTSD symptom severity, as contributors to increased suicide risk among military personnel and veterans who have sustained a TBI.¹¹⁻¹³ To date, however, there is limited research on the potential effects of cumulative head injuries on suicide risk, perhaps owing to the difficulties of disentangling the features and consequences of TBI from those of commonly occurring comorbid conditions, such as PTSD and depression.¹⁴ This is especially relevant for military patients for whom a common event (eg, blast explosion) might contribute to both TBI and psychological injury, such as PTSD. Because TBI has been hypothesized to confer increased risk of suicide through impaired problem solving, disruptions in social functioning, and functional impairment,¹⁵ military personnel who have sustained multiple TBIs throughout their life may be at increased risk for suicide relative to those with a history of fewer TBIs. Although epidemiological research has demonstrated increased anxiety and poorer mental health in persons with a history of multiple TBIs compared with no TBIs or a single TBI,¹⁶ comparative suicide risks were not reported.

The primary aim of the current study was to test the cumulative effect of TBIs on the severity of psychiatric and concussive symptoms and suicide risk in a clinical sample of deployed military personnel. We hypothesized that more TBIs would be associated with increased symptom severity and suicide risk. We also explored the possibility that more TBIs would augment the effects of current psychiatric and concussive symptoms on suicide risk.

Table 1. Sample Descriptors^a

Descriptor	Value
Sex, No. (%)	
Male	150 (93.2)
Female	11 (6.8)
Race, No. (%)	
White	114 (70.8)
African American	25 (15.5)
Hispanic/Latino	15 (9.3)
Asian/Pacific Islander	4 (2.5)
Other	1 (0.6)
Missing	2 (1.2)
Branch of service, No. (%)	
Army	127 (78.9)
Air Force	22 (13.7)
Marines	8 (5.0)
Civilian	4 (2.5)
Rank, No. (%)	
E1-E4	89 (55.3)
E5-E6	50 (31.1)
E7-E9	9 (5.6)
Warrant officer	1 (0.6)
Officer	8 (5.0)
Age, mean (SD), y	27.4 (7.1)
Time in military, mean (SD), y	6.6 (5.5)
Prior deployments, mean (SD)	0.8 (1.1)
Scores, mean (SD)	
Depression subscale	0.9 (0.8)
PCL-M	30.8 (14.2)
Concussive symptoms	3.1 (2.8)
SBQ-R total score	3.5 (1.5)

Abbreviations: PCL-M, PTSD [Posttraumatic Stress Disorder] Checklist-Military Version; SBQ-R, Suicidal Behaviors Questionnaire-Revised.

^a N=161.

Methods

Participants

Participants included 157 military personnel and 4 civilian contractors (N = 161) consecutively referred to an outpatient TBI clinic located at a combat support hospital in Iraq during a 6-month span in 2009. Patients were predominantly male, white, and in the Army and had been in the military for a mean (SD) of 6.6 (5.5) years (range, 0.8-29.0 years). The rank distribution included primarily junior enlisted (rank E1-E4, 55.3%) and noncommissioned officers (E5-E6, 31.1%). Patients had been deployed 0 to 6 times previously (mean [SD], 0.8 [1.1]). Additional sample descriptors are displayed in Table 1.

Procedures

Patients were referred to the outpatient TBI clinic for evaluation and treatment of suspected brain injuries, either directly

from the battlefield or on recommendation of a treating medical provider. More than three-quarters of patients (76.6%) were assessed within 7 days of the index event precipitating referral (median, 2 days). On arrival at the clinic, patients underwent a standardized intake evaluation that included computerized neurocognitive testing, psychological and physical health questionnaires, a clinical interview conducted by a clinical psychologist, and a physical examination conducted by a physician. Written informed consent for the evaluation and treatment was obtained before completion of surveys and administration of testing procedures. A diagnosis of TBI was made by the clinical psychologist and/or examining physician, both of whom were specifically trained in the assessment, diagnosis, and management of TBI, based on the definitional criteria described below. Patients with acute moderate to severe TBI were immediately evacuated from Iraq; only those meeting criteria for mild TBI or no TBI after the most recent injury completed all assessments.

In their clinical interviews, patients were asked how many previous head injuries they had sustained during their deployment and before their deployment (before or during military service). Only previous head injuries that met criteria for a diagnosis of TBI were recorded. Patients were classified into 3 groups based on the total lifetime number of TBIs (ie, current TBI plus total number of previous TBIs): no TBIs (18 patients [11.2%]), single TBI (58 patients [36.0%]), or multiple TBIs (85 patients [52.8%]). Clinical data were stored in a clinic database and then deidentified before analysis. Study approval was obtained from the Brooke Army Medical Center Institutional Review Board, the US Army Medical Research and Materiel Command's Office of Research Protection, and the Multi-National Force-Iraq Institutional Official.

Diagnosis of TBI

Traumatic brain injuries were diagnosed by a licensed clinical psychologist and defined as a traumatically induced structural injury and/or physiological disruption of brain function caused by an external force and indicated by new onset or worsening of at least 1 of the following clinical signs immediately after the event: (1) any period of loss of or decreased level of consciousness; (2) any loss of memory for events immediately before or after the injury; (3) any alteration in mental state at the time of the injury; (4) neurological deficits (transient or not); and (5) intracranial lesion.¹⁷

Measures

Suicide Risk

Suicide risk was measured using the 4-item Suicidal Behaviors Questionnaire-Revised (SBQ-R), a brief self-report measure of past suicidal behaviors and current suicidal desire.¹⁸ The questionnaire assesses 4 domains: lifetime suicidal ideation and/or suicide attempts, frequency of suicidal ideation during the past 12 months, the threat of a suicide attempt, and the self-reported likelihood of suicidal behavior in the future. Items can be summed to obtain an overall metric of suicide risk, with total scores ranging from 3 to 18. Higher scores on the SBQ-R are an indication of greater sui-

cide risk and have been found to reliably differentiate between suicidal and nonsuicidal subgroups in both clinical and nonclinical settings.¹⁸ Internal consistency in the current sample was 0.84 (Cronbach α).

Depression Symptoms

Depression symptoms were measured by the 5-item depression subscale of the Behavioral Health Questionnaire-20.¹⁹ The depression subscale includes items that ask about the frequency of low energy and motivation, not liking oneself, difficulty concentrating, sadness, and hopelessness during the preceding 2 weeks on a scale ranging from 0 (almost always) to 4 (never). The score correlates with other validated measures of depression and happiness in clinical and nonclinical samples.²⁰ The depression subscale total score is obtained by calculating the mean of each item score, and therefore ranges from 0 to 4, with higher scores indicating better health (ie, lower levels of depression). To aid in the interpretation of the results for the purposes of the current study, however, this scale was transformed so that higher scores indicated higher levels of depression. Internal consistency in the current sample was 0.82 (Cronbach α).

PTSD Symptoms

The PTSD symptoms were measured by the PTSD Checklist-Military Version (PCL-M),²¹ a reliable and valid 17-item self-report inventory that assesses the severity of each *DSM-IV*-defined PTSD symptom on a scale from 0 (not at all) to 5 (extremely). Patients were directed to think about their most stressful deployment experience while responding to the PCL-M to ensure that responses were directly related to deployment-related trauma. The total score is obtained by summing each item, resulting in a range of 17 to 85, with higher scores indicating more severe symptoms. Internal consistency in the current sample was 0.93 (Cronbach α).

Concussive Symptoms

Concussive symptoms experienced immediately after the index injury were measured via the history clinical interview section of the Military Acute Concussion Evaluation.²² Symptoms assessed included loss of consciousness, alteration in consciousness, headache, dizziness, memory problems, balance problems, nausea, vomiting, concentration impairment, irritability, visual disturbances, hearing problems, and sleep disruption. The number of symptoms endorsed was summed to provide a metric of concussive symptom severity, with higher numbers indicating more symptoms. Internal consistency in the current sample was 0.82 (Cronbach α).

Statistical Analysis

Generalized linear modeling with robust maximum likelihood estimation was used for mean comparisons and regression analyses owing to skewed symptom scores. Pairwise group comparisons were conducted with Bonferroni correction to minimize type I error. For categorical comparisons, Fisher exact test was used. In terms of power, the current sample size of 161 patients was sufficient (ie, power

Table 2. Means, SDs, and Intercorrelations of Variables^a

Descriptor	1	2	3	4	5
1. SBQ-R	...				
2. Lifetime TBIs	.23 ^b	...			
3. PCL-M	.26 ^b	.34 ^b	...		
4. Depression	.38 ^b	.32 ^b	.77 ^b	...	
5. Concussive symptoms	.20 ^c	.39 ^b	.60 ^b	.61 ^b	...
Mean (SD)	0.46 (1.46)	2.53 (2.79)	30.84 (14.16)	0.89 (0.84)	3.06 (2.75)

Abbreviations: PCL-M, Posttraumatic Stress Disorder Checklist-Military Version; SBQ-R, Suicidal Behaviors Questionnaire-Revised; TBIs, traumatic brain injuries.

^a Values are correlation coefficients. Column headings correspond to the numbered constructs in the left column.

^b $P < .01$.

^c $P < .05$.

>.80) to detect medium-sized effects at $P < .05$ (2-tailed) for all planned analyses.

Results

Cumulative TBI Total and Increased Psychiatric and Concussive Symptom Severity

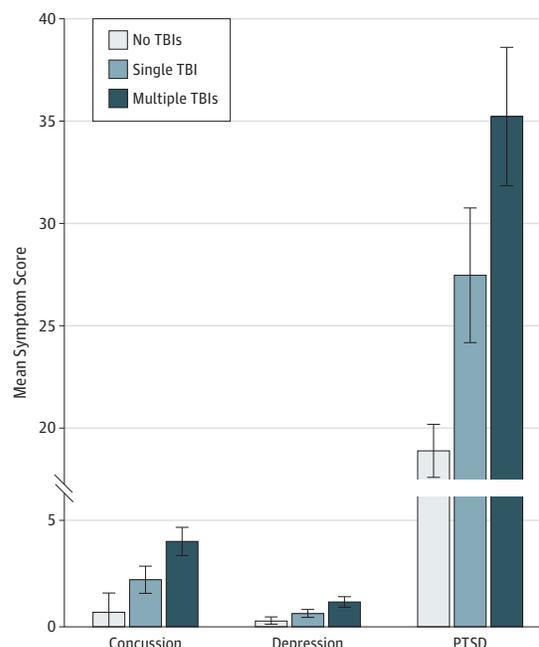
Patients reported a lifetime total of 0 to 19 TBIs (mean [SD], 2.5 [2.8]; median, 2.0). For previous TBIs (ie, TBIs occurring before the most recent injury), patients reported sustaining a mean (SD) of 0.6 (1.7) TBIs (range, 0-15) while deployed and 0.5 (1.1) TBI (range, 0-6) before deployment. Means, SDs, and intercorrelations of all variables are displayed in **Table 2**. Patients were then aggregated into 1 of 3 groups based on lifetime number of TBIs (including the most recent injury): no TBIs, single TBI, or multiple TBIs. Pairwise comparisons with Bonferroni corrections indicated that the following mean (SD) symptom scores were significantly increased in association with increased number of TBIs: depression (no TBIs, 0.3 [0.4]; single TBI, 0.6 [0.7]; and multiple TBIs, 1.2 [0.9]), PTSD (18.9 [2.4], 27.5 [12.2], and 35.3 [15.1], respectively), and concussive symptoms (0.7 [1.7], 2.2 [2.2], and 4.1 [2.8], respectively) (**Figure 1**).

Cumulative TBI Total and Increased Suicide Risk

Specific to lifetime suicide risk (ie, SBQ-R item 1), 18 patients (11.2%) reported past thoughts about suicide, 2 (1.2%) reported developing a specific suicide plan, and 2 (1.2%) reported a previous suicide attempt. Given this distribution, we focused only on lifetime suicidal ideation and dichotomized this variable into any vs no previous suicidal ideation. The likelihood of any past suicidal ideation was significantly increased with the number of TBIs ($\chi^2_2 = 9.524$; $P = .009$), occurring in none of the patients with no TBIs, 6.9% with a single TBI, and 21.7% with multiple TBIs. For suicidal ideation within the past year (ie, SBQ-R item 2), the likelihood was similarly increased with the number of TBIs ($\chi^2_2 = 5.276$; $P = .04$), occurring in none of the patients with no TBIs, 3.4% with a single TBI, and 12.0% with multiple TBIs.

Total SBQ-R scores ranged from 0 (82.0% of patients) to 13 (0.6%). To test the effect of cumulative TBIs on suicide risk while controlling for symptom severity, we used linear regres-

Figure 1. Traumatic Brain Injury (TBI) Groups



Mean symptom scores with 95% CIs by TBI group. For all scales, pairwise comparisons with Bonferroni corrections revealed significant differences in scores ($P < .05$) between the no-TBI and single-TBI groups and between the single- and multiple-TBI groups. PTSD indicates posttraumatic stress disorder.

sion with robust maximum likelihood estimation. Results are displayed in **Table 3** (model 1) and suggest that the number of TBIs is significantly associated with increased suicide risk above and beyond the effects of severity for depression, PTSD, and concussive symptoms.

Effect of Cumulative TBI Total on Relationship Between Depression and Suicide Risk

We also explored the possibility that cumulative TBIs might augment the effects of psychological symptom severity on suicide risk. Separate interaction terms for the number of TBIs with depression, PTSD, and concussive symptom severity were independently added to the model described above. Only the interaction of cumulative TBIs with depression severity was statistically significant, however, indicat-

Table 3. Results of Generalized Linear Regressions Predicting Suicidal Behaviors Questionnaire–Revised Total Score

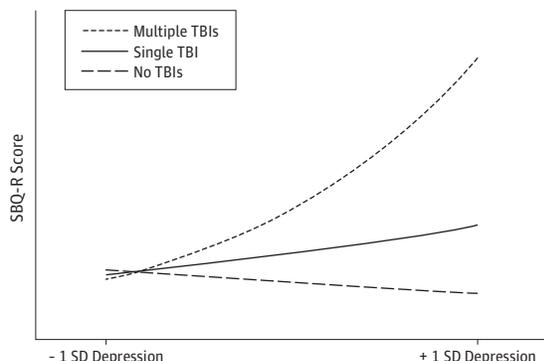
Variable	Model 1		Model 2	
	β (SE)	P Value	β (SE)	P Value
TBI group	.214 (.098)^a	.03	-.105 (.164)	.52
Depression symptoms	.740 (.314)^a	.02	-.243 (.291)	.40
PTSD symptoms	-.007 (.010)	.44	-.007 (.010)	.46
Concussion symptoms	-.029 (.043)	.50	-.028 (.043)	.52
Depression × TBI group ^b580 (.283)^a	.04

Abbreviations: PTSD, posttraumatic stress disorder; TBI, traumatic brain injury.

^a Values in bold indicate statistically significant coefficients.

^b Interaction between depression and TBI group.

Figure 2. Depression, Suicide Risk, and Traumatic Brain Injury (TBI)



Suicide risk as a function of the interaction between depression severity and TBI group. SBQ-R indicates Suicidal Behaviors Questionnaire–Revised.

ing that the relationship of depression symptoms with suicide risk strengthened as the number of lifetime TBIs increased (Table 3, model 2). This interaction is graphically depicted in Figure 2. The interaction of cumulative TBIs with either PTSD or concussive symptom severity did not significantly predict suicide risk.

Discussion

Results of the current study supported our hypothesis that military personnel who have sustained more TBIs report more severe psychological symptoms and greater suicide risk. In addition, the significant interaction of depression severity with number of TBIs suggests that the effects of depression on suicide risk are augmented by cumulative TBIs. This is noteworthy because military personnel who have sustained multiple head injuries might be especially vulnerable to suicide risk when experiencing emotional distress.

Results are consistent with the fluid vulnerability theory,²³ which posits that some individuals can experience heightened risk for suicide over time owing to a combination of increased predisposing vulnerabilities that can increase sensitivity to emotional distress. Traumatic brain injuries probably serve as a chronic risk factor for suicidal behaviors, most likely because of their association with a number of well-established suicide risk factors frequently seen within military populations, including psychiatric disorders,

impaired problem solving, and aggression.^{6,24-26} Repetitive traumatic head injuries are believed to exacerbate these effects,²⁷ which may impart even more vulnerability to suicidal behaviors over time and/or contribute to increased sensitivity to the deleterious effects of depressed mood. Although cumulative negative effects of repetitive TBIs on neurological functioning and neurocognitive performance have been established,²⁸ the cumulative effects of repetitive TBIs on psychiatric symptoms have received only minimal empirical attention. Our current results converge with those of population-based research suggesting increased psychiatric distress among individuals with a history of multiple TBIs¹⁵ and expand these conclusions to military personnel.

Cumulative TBIs may be a causal factor for suicidal behavior in that TBI increases impulsivity and emotional distress, which in turn can increase suicide risk. Alternatively, it is possible that cumulative TBIs and suicidal behaviors are consequences of the common underlying risk factor of impulsivity. Regardless of the direction of causality, our current results suggest that assessing the number of TBIs experienced by a patient may help in determining the more enduring risk for suicidal behaviors over time. Longitudinal research studies that track the cumulative effects of TBI are needed to clarify the pathways from repetitive TBIs to suicide risk over time.

The current study has some limitations, including the use of self-report methods, which can be vulnerable to recall bias. Future studies that also incorporate behavioral and/or objective methods of measuring symptom severity and/or psychiatric diagnosis would be useful for confirming these results. As discussed above, the cross-sectional design of our study also limits our ability to establish causality, and the use of a single clinical sample might restrict generalizability. Furthermore, conclusions are limited to suicidal ideation only and therefore do not necessarily generalize to specific planning, suicide attempts, and death by suicide. Additional longitudinal studies with larger samples will therefore be needed to better understand temporal relationships among TBI, depression, PTSD, and a broader range of suicide risk. Finally, the environmental context of the current study (ie, in a combat zone within days of injury) may limit the generalizability of findings to more conventional clinical settings, where patients typically present months to years after their most recent TBI (eg, Veterans Affairs clinics). Despite these limitations, the current study provides valuable information regarding the relationship between cumulative TBIs and suicide risk among injured military personnel.

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Disclaimer: The views expressed in this article are those of the authors and do not necessarily represent the official position or policy of the US government, the Department of Veterans Affairs, the Department of Defense, or the Department of the Army.

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