Association Between Traumatic Brain Injury and Risk of Posttraumatic Stress Disorder in Active-Duty Marines

Kate A. Yurgil, PhD; Donald A. Barkauskas, PhD; Jennifer J. Vasterling, PhD; Caroline M. Nievergelt, PhD; Gerald E. Larson, PhD; Nicholas J. Schork, PhD; Brett T. Litz, PhD; William P. Nash, MD; Dewleen G. Baker, MD; for the Marine Resiliency Study Team

IMPORTANCE Whether traumatic brain injury (TBI) is a risk factor for posttraumatic stress disorder (PTSD) has been difficult to determine because of the prevalence of comorbid conditions, overlapping symptoms, and cross-sectional samples.

OBJECTIVE To examine the extent to which self-reported predeployment and deployment-related TBI confers increased risk of PTSD when accounting for combat intensity and predeployment mental health symptoms.

DESIGN, SETTING, AND PARTICIPANTS As part of the prospective, longitudinal Marine Resiliency Study (June 2008 to May 2012), structured clinical interviews and self-report assessments were administered approximately 1 month before a 7-month deployment to Iraq or Afghanistan and again 3 to 6 months after deployment. The study was conducted at training areas on a Marine Corps base in southern California or at Veterans Affairs San Diego Medical Center. Participants for the final analytic sample were 1648 active-duty Marine and Navy servicemen who completed predeployment and postdeployment assessments. Reasons for exclusions were nondeployment (n = 34), missing data (n = 181), and rank of noncommissioned and commissioned officers (n = 66).

MAIN OUTCOMES AND MEASURES The primary outcome was the total score on the Clinician-Administered PTSD Scale (CAPS) 3 months after deployment.

RESULTS At the predeployment assessment, 56.8% of the participants reported prior TBI; at postdeployment assessment, 19.8% reported sustaining TBI between predeployment and postdeployment assessments (ie, deployment-related TBI). Approximately 87.2% of deployment-related TBIs were mild; 250 of 287 participants (87.1%) who reported posttraumatic amnesia reported less than 24 hours of posttraumatic amnesia (37 reported ≥24 hours), and 111 of 117 of those who lost consciousness (94.9%) reported less than 30 minutes of unconsciousness. Predeployment CAPS score and combat intensity score raised predicted 3-month postdeployment CAPS scores by factors of 1.02 (P < .001; 95% CI, 1.02-1.02) and 1.02 (P < .001; 95% CI, 1.01-1.02) per unit increase, respectively. Deployment-related mild TBI raised predicted CAPS scores by a factor of 1.23 (P < .001; 95% CI, 1.11-1.36), and moderate/severe TBI raised predicted scores by a factor of 1.71 (P < .001; 95% CI, 1.37-2.12). Probability of PTSD was highest for participants with severe predeployment symptoms, high combat intensity, and deployment-related TBI. Traumatic brain injury doubled or nearly doubled the PTSD rates for participants with less severe predeployment PTSD symptoms.

CONCLUSIONS AND RELEVANCE Even when accounting for predeployment symptoms, prior TBI, and combat intensity, TBI during the most recent deployment is the strongest predictor of postdeployment PTSD symptoms.

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T
raumatic brain injury (TBI) is common. According to a 2010 Centers for Disease Control and Prevention report, at least 1.7 million Americans annually sustain TBI. A significant number of injury survivors join more than 5 million (approximately 2%) Americans already living with TBI-related disabilities, which comprise a wide range of medical, cognitive, emotional, and behavioral impairments. The estimated economic burden of TBI in the United States in 2000, prior to initiation of the Iraq and Afghanistan conflicts, was approximately $60 billion annually.

Pervasive use of improvised explosive devices (IEDs), rocket-propelled grenades, and land mines in the Iraq and Afghanistan theaters has brought TBI and its effect on health outcomes into public awareness. Blast injuries have been deemed signature wounds of these conflicts, with an estimated 52% of deployment-related TBI cases caused by IEDs. Of Operations Enduring Freedom, Iraqi Freedom, and New Dawn service members, approximately 10% to 20% reported mild TBI or concussion, and nearly 60% of those reported exposure to more than 1 blast.

War-related TBI is not new, having become prevalent during World War I and remaining medically relevant in World War II and beyond. Medicine’s past attempts to disentangle the pathophysiology of war-related TBI parallels current lines of inquiry and highlights limitations in methods and attribution of the cause of symptoms, be it organic, psychological, or behavioral. Thus far, cross-sectional data from the Operations Enduring Freedom, Iraqi Freedom, and New Dawn conflicts reveal significantly higher rates of psychiatric symptoms, including posttraumatic stress disorder (PTSD), in deployed than in nondeployed service members. Moreover, self-reported TBI and PTSD symptoms show considerable overlap. Symptoms of PTSD are reported at approximately double the rate by service members who show positive results on screening for mild TBI in comparison with those who report no TBI. These cross-sectional studies limit causal inference and stress the need for longitudinal data to define further the contribution of war-related TBI to PTSD. Using data from the Marine Resiliency Study, a prospective, longitudinal study of infantry Marines, we examined whether deployment-related TBI predicts PTSD symptom severity when accounting for combat intensity and predeployment characteristics.

Methods

Study Design and Participants
We extracted data from a longitudinal study of 2600 active-duty Marine and Navy servicemen from 4 infantry battalions of the First Marine Division stationed in southern California. Assessments were conducted between July 14, 2008, and May 24, 2012, and were centered on the deployments of each battalion. Servicemen were evaluated approximately 1 month before a 7-month deployment to Iraq or Afghanistan, 1 week after deployment, and 3 and 6 months after deployment. For this study, we used data collected at predeployment, as well as 1 week and 3 months after deployment. Data from the 6-month postdeployment evaluation were not analyzed because of reduced follow-up rates. This study was approved by the institutional review boards of the University of California, San Diego; the Veterans Affairs San Diego Research Service; and the Naval Health Research Center (University of California, San Diego, and Veterans Affairs San Diego Research Service service approval 070533), and written informed consent was obtained from all participants. Participants received financial compensation for each study visit in which a blood draw occurred (ie, predeployment, 3-months, and 6-months postdeployment).

The Figure shows the sampling composition and exclusions. Of the 2600 servicemen assessed at predeployment, 34 did not deploy and were excluded a priori as well as 66 officers who were significantly older (P < .001) and had lower Combat Experience Scale (CES) scores (P < .001) than enlisted participants. Forty-five of the 66 officers (68%) were missing cognitive ability scores on a military enlistment test (Armed Forces Qualification Test [AFQT]), an important variable associated with resilience. The 22% of officers with available AFQT scores scored significantly higher than current enlisted participants (P < .001). Of the remaining 2500 individuals, 1829 completed the 3-month postdeployment assessment. Of these, 181 were excluded for missing data on measures used in the present analysis. The final analytic sample included 1648 participants.

Measures
Complete Marine Resiliency Study methods are described elsewhere. Measures relevant to the present study are described here. Posttraumatic stress symptoms were assessed using the Clinician-Administered PTSD Scale (CAPS), a 17-item criterion standard, structured diagnostic interview developed by the National Center for PTSD, administered before deployment and 3 months after deployment. We captured

<table>
<thead>
<tr>
<th>Figure. Flowchart</th>
</tr>
</thead>
<tbody>
<tr>
<td>2600 Active-duty participants at predeployment (baseline) assessment</td>
</tr>
<tr>
<td>34 Did not deploy after baseline</td>
</tr>
<tr>
<td>66 Officers</td>
</tr>
<tr>
<td>2500 Deployed enlisted men eligible for analysis</td>
</tr>
<tr>
<td>1829 Deployed enlisted men at postdeployment assessment</td>
</tr>
<tr>
<td>1648 Analyzed</td>
</tr>
<tr>
<td>671 Lost to follow-up</td>
</tr>
<tr>
<td>181 Missing data</td>
</tr>
</tbody>
</table>
TBI and PTSD in Active-Duty Marines

Predeployment differences between participants in the final sample and nonparticipants (ie, servicemen assessed at predeployment only or excluded otherwise) were tested using a paired, 2-tailed t test, exact conditional test of proportions, or χ², as appropriate. Differences in predeployment CAPS scores were analyzed using zero-inflated negative binomial regression (ZINBR) because of overdispersion.

The CAPS outcome scores were positively skewed, overdispersed, and had an excess of zero scores (Supplement [eFigure]). Zero-inflated negative binomial regression was the best-fitting model for our data (Supplement [eAppendix and eTable 2]) and was used to test effects of predeployment PTSD symptoms, combat intensity, and prior and deployment-related TBI on 3-month postdeployment PTSD symptoms. The ZINBR model accounts for a positively skewed integer-valued distribution with a high proportion of zero scores. This model assumes that our sample contains a mixture of participants whose CAPS outcome scores are generated by the standard negative binomial distribution and those who have zero probability of a CAPS outcome score greater than zero (eg, resulting from nontraumatic CAPS event and possible genetic or biological resilience). An observed CAPS score of zero could come from either group. Zero-inflated negative binomial regression uses maximum likelihood to model outcomes via 2 component models: logistic regression (the zero model) predicts the probability of a CAPS outcome score of zero, and negative binomial regression (the count model) predicts change in CAPS score. Throughout this article we refer to predicting the odds of a zero vs nonzero outcome as the zero model and predicting nonzero outcomes as the count model.

Model estimates and predeployment symptom severity, combat intensity, and TBI were used to predict postdeployment symptom severity. Additional ZINBR models assessed the effects of TBI-related attributes, including injury severity (mild vs moderate/severe), time since most recent TBI, single vs multiple deployment-related TBIs, and group comparisons among deployment-related TBIs with LOC, TBI without LOC, and no deployment-related TBI.

Results

Sample Characteristics

Predeployment sample characteristics were similar to demographics of other deployed service members (Table 1). Participants were younger (mean [SD] age, 22.4 [3.3] vs 23.0 [3.4] years), more likely to be junior enlisted (74.1% vs 62.2%), and were less likely to have had prior deployments (45.3% vs 62.0%) compared with nonparticipants. Approximately 31.8% of participants were married. Participants had lower childhood trauma scores (39.8 [13.2] vs 41.6 [14.8]), and better predeployment 12-item Short-Form Health Survey physical health component scores (53.9 [6.3] vs 52.6 [6.8]) than nonparticipants. Participants and nonparticipants did not differ significantly in other demographic and predeployment factors, including AFQT scores, depression, anxiety, CAPS scores, 12-item Short-Form Health Survey mental health scores, and predeployment TBI rates.
Table 2 reports the final sample characteristics. Of the total number of respondents, 56.8% reported probable TBI before the index (ie, most recent) deployment. At the 3-month post-deployment assessment, 40 of the participants (2.4%) had CAPS scores of 65 or more, and 327 individuals (19.8%) reported sustaining TBI after predeployment, with 295 (17.9%) reporting TBI during the index deployment. Of the 32 participants reporting nondeployment TBI between predeployment and 3-month postdeployment assessments, 2 sustained TBI after predeployment but before the index deployment, and 24 sustained TBI after their index deployment but before their follow-up assessment; the event timing of 6 TBIs could not be verified.

There were no significant differences between deployment TBI and nondeployment TBI sustained between predeployment and postdeployment on model outcomes; thus, nondeployment TBIs were included in the main analysis. Mean time since most recent TBI was 200 (126) days. Of the 327 individuals who sustained TBI after the predeployment assessment, 112 participants (34.3%) reported more than 1 TBI, and 285 TBIs (87.2%) were categorized as probably mild. 208 of 327 individuals (63.6%) reported alteration of consciousness without LOC, 250 of 287 (87.1%) who reported PTA indicated less than 24 hours of PTA (37 reported >24 hours), and 111 of 117 participants (94.9%) who lost consciousness reported less than 30 minutes of LOC. Severity of 4 TBIs (1.2%) was unknown. Participants who sustained TBI after the predeployment assessment were more likely than others to have had prior TBI and reported more severe predeployment PTSD symptoms and greater combat intensity during their index deployment.

Zero-Inflated Negative Binomial Regression

Results of ZINBR are reported in Table 3. A significant main effect reflected a predictor’s association with postdeployment CAPS scores given a predeployment CAPS score of zero, mean scores on all other continuous predictors, and reference group membership for categorical predictors. Significant interactions out of all possible tested are reported.

Zero Model: Predicting Absence of PTSD Symptoms

Logistic regression was used to predict probability of a 3-month postdeployment CAPS score of zero. Coefficients were exponentiated and interpreted as odds of a zero CAPS score. The zero model intercept reflects a 27.1% base probability of having a postdeployment CAPS score of zero given the participant was white, non-Hispanic, from battalion 1, had no predeployment or deployment TBI, and had average scores on all other continuous predictors.

For the zero model, deployment-related TBIs were collapsed across severity because the small number of moderate/severe TBIs caused problems with model convergence. Unit increases in predeployment CAPS scores decreased the odds
of an outcome (ie, postdeployment) CAPS score of zero by a factor of 0.92 (7.7%; \(P < .001\)). Unit increases in combat intensity reduced the odds by a factor of 0.96 (3.6%; \(P < .001\)). Prior TBI reduced the odds of having an outcome CAPS score of zero by a factor of 0.65 (35.5%; \(P < .01\)), and deployment-related TBI reduced the odds by a factor of 0.34 (66.1%; \(P < .01\)). There were no effects of TBI with vs without LOC, time since most recent TBI, or single vs multiple deployment-related TBI on the absence of postdeployment symptoms.

### Count Model: Predicting PTSD Symptom Severity

The count model predicted the postdeployment CAPS scores being generated from a negative binomial distribution. Exponentiated coefficients of the counts model represent multiplicative change in predicted CAPS score per unit change in a given predictor. The intercept reflects a predicted postdeployment CAPS score of 12.54 given the participant was white, non-Hispanic, from battalion 1, had no TBI, had a predeployment CAPS score of zero, and had average scores on all other continuous predictors.

Predeployment CAPS score and combat intensity score raised the predicted 3-month postdeployment CAPS score by raised the predicted 3-month postdeployment CAPS score by factors of 1.02 (1.9%; \(P < .001\)) and 1.02 (1.5%; \(P < .001\)) per unit increase, respectively. Prior (ie, pre-index deployment) TBI raised the predicted CAPS outcome score by a factor of 1.08 (7.5%), but the effect was not significant (\(P < .08\)). Deployment-related mild TBI raised the predicted CAPS score by a factor of 1.23 (22.6%; \(P < .001\)), and deployment-related moderate/severe TBI raised the predicted CAPS score by a factor of 1.71 (70.5%; \(P < .001\)). Dividing the estimated coefficients for deployment-related TBI by combat intensity yielded the equivalent of a 14.0-point increase in combat intensity for participants reporting mild TBI, and a 36.6-point increase for those reporting moderate/severe TBI. There were no effects of deployment-related TBI with vs without LOC, time since recent TBI, or single vs multiple TBI on postdeployment symptom severity.

There was a relatively small interaction effect that accounted for less than 1% change in 3-month postdeployment CAPS score. Unit increases in AFQT increased the predicted CAPS score by 0.8% (\(P < .001\)), but this effect was reduced by roughly two-thirds in participants with predeployment TBI (\(P < .02\)).

The overall effects of predeployment symptoms, combat intensity, and TBI on postdeployment PTSD symptoms were confirmed using logistic regression to determine the effects of the same predictors as in the final ZINBR model on the categorical outcome of PTSD vs no PTSD at 3-month postdeployment assessment (Supplement eMethods, eResults, and eTable 3).

### Predictions

Predeployment CAPS scores, combat intensity, and deployment-related mild TBI were used to predict the probability that
TBI further increased predicted PTSD rates for this group before deployment (12.3%), and deployment-related mild predicted PTSD rates for those who reported partial symptoms bat intensity (>6%). Higher combat intensity increased pre-of postdeployment PTSD at 3 months, even with low com-

Participants whose predeployment CAPS scores met the criteria for partial PTSD or PTSD had higher predicted probabilities for partial PTSD or PTSD. Deployment-related mild TBI further increased predicted PTSD rates for this group (21.1%).

Table 3. Zero-Inflated Negative Binomial Regression Predicting Postdeployment PTSD Symptoms

<table>
<thead>
<tr>
<th>Model</th>
<th>Variable</th>
<th>Estimate (SE)</th>
<th>P Value</th>
<th>Predicted CAPS Totala</th>
<th>Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count (Intercept)</td>
<td>2.53 (0.06)</td>
<td>&lt;.001</td>
<td>12.54</td>
<td>(11.10-14.17)</td>
<td></td>
</tr>
<tr>
<td>Battalion 2</td>
<td>-0.03 (0.06)</td>
<td>.65</td>
<td>0.97 (0.86-1.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battalion 3</td>
<td>-0.05 (0.06)</td>
<td>.46</td>
<td>0.96 (0.85-1.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battalion 4</td>
<td>0.13 (0.07)</td>
<td>.06</td>
<td>1.14 (1.00-1.31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAPS score, predeployment</td>
<td>0.02 (0.00)</td>
<td>&lt;.001</td>
<td>1.02 (1.02-1.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFQT</td>
<td>0.01 (0.00)</td>
<td>&lt;.001</td>
<td>1.01 (1.01-1.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBI, predeployment</td>
<td>0.07 (0.04)</td>
<td>.07</td>
<td>1.08 (0.99-1.16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFQT × TBI, predeployment</td>
<td>-0.0 (0.00)</td>
<td>.02</td>
<td>1.00 (0.99-1.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combat Experience Score</td>
<td>0.01 (0.00)</td>
<td>&lt;.001</td>
<td>1.02 (1.01-1.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild TBI, deploymentb</td>
<td>0.20 (0.05)</td>
<td>&lt;.001</td>
<td>1.23 (1.11-1.36)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate/severe TBI, deploymentb</td>
<td>0.53 (0.11)</td>
<td>&lt;.001</td>
<td>1.71 (1.37-2.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero (Intercept)</td>
<td>-0.10 (0.25)</td>
<td>&lt;.001</td>
<td>27.10%</td>
<td>(18.60%-37.69%)</td>
<td></td>
</tr>
<tr>
<td>Battalion 2</td>
<td>0.93 (0.24)</td>
<td>&lt;.001</td>
<td>2.52</td>
<td>(1.60-4.06)</td>
<td></td>
</tr>
<tr>
<td>Battalion 3</td>
<td>0.63 (0.25)</td>
<td>.01</td>
<td>1.87</td>
<td>(1.14-3.07)</td>
<td></td>
</tr>
<tr>
<td>Battalion 4</td>
<td>0.33 (0.29)</td>
<td>.26</td>
<td>1.39</td>
<td>(0.79-2.45)</td>
<td></td>
</tr>
<tr>
<td>CAPS score, predeployment</td>
<td>-0.08 (0.01)</td>
<td>&lt;.001</td>
<td>0.92</td>
<td>(0.90-0.94)</td>
<td></td>
</tr>
<tr>
<td>TBI, predeployment</td>
<td>-0.44 (0.15)</td>
<td>.003</td>
<td>0.64</td>
<td>(0.48-0.86)</td>
<td></td>
</tr>
<tr>
<td>Combat Experience Score</td>
<td>-0.04 (0.01)</td>
<td>&lt;.001</td>
<td>0.96</td>
<td>(0.94-0.98)</td>
<td></td>
</tr>
<tr>
<td>TBI, deploymentb,c</td>
<td>-1.08 (0.30)</td>
<td>&lt;.001</td>
<td>0.34</td>
<td>(0.19-0.62)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: AFQT, Armed Forces Qualification Test; CAPS, Clinician-Administered PTSD Scale; PTSD, posttraumatic stress disorder; TBI, traumatic brain injury.

* For the zero model, base probability (%) of a predicted CAPS total score, 0.

b There were no significant differences between deployment and nondeployment TBI sustained between predeployment and postdeployment assessments (n = 32). Thus, nondeployment TBI was included in the analysis to account for any potential effects on PTSD outcomes.27

c For the zero model, deployment-related TBIs were collapsed across severity because of the small number of moderate/severe TBIs causing problems with model convergence.

Discussion

As expected, both predeployment psychiatric symptoms and combat intensity significantly predicted postdeployment PTSD symptoms. Predeployment psychiatric conditions have been deemed a risk factor for PTSD and other mental health problems during deployment.40 Likewise, prior psychological trauma46,41 and extensive combat exposure16,42,43 may increase PTSD risk after combat deployment.

Independent of the above effects, TBI sustained before the index deployment was associated with more severe postdeployment PTSD symptoms. According to our model, deployment-related TBIs nearly double the likelihood of postdeployment PTSD for participants who reported minimal to no symptoms before deployment. Probability of postdeployment PTSD was greatest for participants reporting prior psychiatric symptoms and deployment-related TBI. However, of the 16 participants with predeployment PTSD, 8 considerably improved (postdeployment CAPS range, 0-35) and 3 slightly improved (range, 50-78), whereas 3 worsened (range, 78-94). In contrast to those with improved symptoms, participants with persistent symptoms reported higher combat intensity (mean score, 22.7 vs 8.4) and 2 of the 3 reported deployment-related TBI. These findings parallel reported symptom trajectories for deployed service members in which 8% showed improvement in PTSD symptoms and 2.2% showed continuation of severe symptoms.44

Prior cross-sectional studies have also reported associations between TBI and PTSD,45,46 although injury severity may govern the association.47,48 Higher morbidity and use of medical services are associated with severe TBI, whereas mental

3-month postdeployment CAPS scores would fall within defined symptom ranges for partial PTSD and PTSD while holding all other variables constant (Table 4). Predeployment CAPS scores used for prediction were 0 (no symptoms), 19 (healthy/ minimally symptomatic; range, 1-39), 52 (partially PTSD; range, 40-64), and 65 (PTSD; scores ≥65).23 Low and high combat intensity were defined as CES scores of 5 (25th percentile) and 19 (75th percentile), respectively.

Based on study outcomes, participants with no predeployment symptoms, low combat intensity, and no deployment-related TBI were ascertained to have a predicted 3-month postdeployment CAPS score of 7.23, with less than 1% probability of partial PTSD or PTSD. Deployment-related mild TBI raised the predicted CAPS score slightly to 11.45, with 1.5% probability of partial PTSD.

Participants who were minimally symptomatic before deployment had low combat intensity, and those with no TBI had less than 4% predicted probability of postdeployment partial PTSD (3.2%) and PTSD (0.2%). High combat intensity increased predicted rates to 6.9% for partial PTSD and 0.8% for PTSD. In addition, deployment-related mild TBI nearly doubled outcome rates to 12.4% for partial PTSD and 2.4% for PTSD.

With the minimally symptomatic group, participants whose predeployment CAPS scores met the criteria for partial PTSD or PTSD had higher predicted probabilities of postdeployment PTSD at 3 months, even with low combat intensity (>6%). Higher combat intensity increased predicted PTSD rates for those who reported partial symptoms before deployment (12.3%), and deployment-related mild TBI further increased predicted PTSD rates for this group (21.1%).
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Table 4. Predictions of Postdeployment CAPS Scores and Outcome Probabilities

<table>
<thead>
<tr>
<th>Predeployment Symptom Severity (N = 1648)</th>
<th>Combat Intensity</th>
<th>Mild Deployment TBI</th>
<th>Predicted Mean Postdeployment CAPS Score (95% CI)</th>
<th>% Predicted Probability of Partial PTSD (95% CI)</th>
<th>% Predicted Probability of PTSD (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No symptoms (n = 243)</td>
<td>Low</td>
<td>No</td>
<td>7.23 (6.10-8.36)</td>
<td>0.38 (0.27-0.51)</td>
<td>0.01 (0.00-0.02)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>11.45 (10.18-12.72)</td>
<td>1.50 (1.28-1.75)</td>
<td>0.05 (0.01-0.10)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>No</td>
<td>10.29 (9.00-11.58)</td>
<td>1.35 (1.13-1.58)</td>
<td>0.04 (0.01-0.09)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>14.95 (13.90-16.00)</td>
<td>3.88 (3.51-4.27)</td>
<td>0.26 (0.16-0.36)</td>
</tr>
<tr>
<td>Minimally symptomatic (n = 1283)</td>
<td>Low</td>
<td>No</td>
<td>14.17 (13.43-14.91)</td>
<td>3.22 (2.87-3.57)</td>
<td>0.18 (0.10-0.27)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>18.63 (18.09-19.18)</td>
<td>7.12 (6.63-7.63)</td>
<td>0.77 (0.61-0.95)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>No</td>
<td>18.13 (17.47-18.80)</td>
<td>6.93 (6.43-7.43)</td>
<td>0.75 (0.59-0.93)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>23.21 (22.79-23.63)</td>
<td>12.44 (11.80-13.11)</td>
<td>2.37 (2.08-2.68)</td>
</tr>
<tr>
<td>Partial PTSD (n = 106)</td>
<td>Low</td>
<td>No</td>
<td>29.40 (29.13-29.67)</td>
<td>19.01 (18.27-19.79)</td>
<td>6.21 (5.74-6.69)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>36.25 (36.05-36.45)</td>
<td>24.13 (23.30-24.96)</td>
<td>12.35 (11.72-13.01)</td>
</tr>
<tr>
<td>PTSD (n = 16)</td>
<td>Low</td>
<td>No</td>
<td>37.89 (37.68-38.09)</td>
<td>24.97 (24.10-25.83)</td>
<td>14.02 (13.35-14.96)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>46.55 (46.36-46.75)</td>
<td>27.44 (26.57-28.32)</td>
<td>23.27 (22.47-24.11)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>No</td>
<td>46.54 (46.34-46.73)</td>
<td>27.42 (26.54-28.29)</td>
<td>23.27 (22.44-24.09)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>57.14 (56.95-57.33)</td>
<td>27.32 (26.45-28.19)</td>
<td>34.36 (33.44-35.29)</td>
</tr>
</tbody>
</table>

Abbreviations: CAPS, Clinician-Administered PTSD Scale; PTSD, posttraumatic stress disorder; TBI, traumatic brain injury.

* CAPS scores used for prediction were no symptoms (score, 0), healthy/minimally symptomatic (median score, 19; range, 1-39), partial PTSD (median score, 52; range, 40-64), and PTSD scores ≥65.23

1 Low and high combat intensity were Combat Experience Scale scores 5 (25th percentile) and 19 (75th percentile), respectively.

1 Predicted probability of a continuous outcome CAPS score that falls within defined symptoms ranges for partial PTSD and PTSD.

1 Of the 16 participants with predeployment PTSD, 8 improved considerably (postdeployment CAPS range, 0-35) and 3 improved slightly (range, 50-78). Symptoms of 3 worsened (range, 78-94); these participants had higher combat intensity (Combat Experience Scale mean score, 22.7 vs 8.4), and 2 of the 3 sustained deployment-related TBI compared with those whose symptoms improved.

Health diagnoses, including PTSD, are more frequent in patients with mild TBI. In the present study, however, postdeployment CAPS scores increased with TBI severity. More severe TBI in our participants may reflect more severe physical injury, which has been shown to increase the risk of PTSD.49 Higher CAPS scores may also reflect nonspecific symptoms that overlap with TBI sequelae. Alternatively, perhaps the overall contexts surrounding severe TBI were more emotionally traumatic than contexts surrounding milder injuries. Although we adjusted for overall combat intensity, that adjustment would not account for the characteristics of any particular traumatic event.

A possible contributor to the overlap of TBI and PTSD symptoms might be that the emotional salience of the event contiguous with TBI may exceed that of the typical civilian or combat-related traumatic event, thereby increasing PTSD risk. Structural and functional brain changes following TBI are likely additional contributors to PTSD outcomes. Prefrontal cortical networks implicated in PTSD50-52 may be damaged during the course of mild TBI, consequently affecting fear memory processing.53 Correlations between white matter integrity, cortical function, and postconcussive symptoms provide initial evidence that brain changes associated with mild TBI are distinct from those associated with PTSD or depression.54-57 Ultimately, high-resolution neuroimaging may help to clarify whether TBI severity reflects neural tissue injury that impedes emotional recovery from stressful events.

There is growing interest in the persistence of postconcussive symptoms and the extensive overlap with anxiety disorders, including PTSD.58-60 Brain injuries also have been linked to increased suicidality, particularly for individuals with comorbid psychiatric and emotional disturbances, such as PTSD and depression.61-63 Comorbidity of TBI and PTSD is not unique to deployed service members; motor vehicle accidents and interpersonal assault are 2 common causes of TBI and PTSD in civilians.64-66 Furthermore, recurrent TBI from contact sports has, as with repeated blast exposure, been linked to greater mental health problems and neurologic abnormalities.67,68 Several study limitations should be addressed. As in prior studies,29,59,70,71 we used retrospective self-report measures, including TBI accounts, which limit causal inference and reflect potentially inconsistent documentation of in-theater events. Furthermore, TBI may be a marker for a traumatic event not otherwise captured by the CES.

In addition, results from the present study may not be generalizable to other populations. Demographic differences between participants and nonparticipants likely reflect the older age and greater military experience of nonparticipants, most of whom were lost to follow-up, possibly resulting from reassignment or discharge. Participation bias likely accounts for mental and physical health differences between participants and nonparticipants. Similar findings have been documented previously and have not been shown to affect study outcomes. Finally, PTSD symptoms were positively skewed, and CAPS threshold scores for partial PTSD and PTSD that were validated in civilians may be conservative for diagnosis in a military population.
Despite these limitations, the present study’s prospective design and inclusion of prior psychological and physical trauma are unique contributions to the study of TBI and PTSD. Results suggest that deployment-related TBI may be an important risk factor for PTSD, particularly for individuals with symptoms related to a prior traumatic event.

**REFERENCES**


Predeployment and in-theater diagnoses of mild traumatic brain injury (TBI) and posttraumatic stress disorder (PTSD) are discussed in the context of active-duty Marines. The Report to Congress on Mild Traumatic Brain Injury in the United States and Clinical Practice Guidelines and Recommendations provide a framework for understanding the prevalence and management of these conditions.


The contribution of prior psychological symptoms and combat exposure to post IRAQ deployment mental health in the UK military is discussed. J Trauma Stress. 2009;22(1):11-19.


