ORIGINAL ARTICLE

Longitudinal Effects of Mild Traumatic Brain Injury and Posttraumatic Stress Disorder Comorbidity on Postdeployment Outcomes in National Guard Soldiers Deployed to Iraq

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Context: Troops deployed to Iraq and Afghanistan are at high risk for exposure to combat events resulting in mild traumatic brain injury (MTBI) or concussion and posttraumatic stress disorder (PTSD). The longer-term impact of combat-related concussion/MTBI and comorbid PTSD on troops' health and well-being is unknown.

Objective: To assess longitudinal associations between concussion/MTBI and PTSD symptoms reported in theater and longer-term psychosocial outcomes in combat-deployed National Guard soldiers.

Design: Longitudinal cohort study. Participants were surveyed in Iraq 1 month before returning home (time 1) and 1 year later (time 2). Self-reports of concussion/MTBI and PTSD were assessed at times 1 and 2. Based on time 1 concussion/MTBI status (defined as an injury during deployment with loss of consciousness or altered mental status) and time 2 postdeployment probable PTSD status, soldiers were compared on a range of time 2 psychosocial outcomes.

Participants: Nine hundred fifty-three US National Guard soldiers.

Setting: The time 1 sample was assessed during redeployment transition briefings held at military installations in the Iraq combat theater. The time 2 sample was assessed using mailed surveys sent to the homes of US National Guard service members.

Main Outcome Measures: Postconcussive, depression, and physical symptoms; alcohol use; social functioning; and quality of life assessed at time 2 using valid clinical instruments.

Results: The rate of self-reported concussion/MTBI during deployment was 9.2% at time 1 and 22.0% at time 2. Soldiers with a history of concussion/MTBI were more likely than those without to report postdeployment postconcussive symptoms and poorer psychosocial outcomes. However, after adjusting for PTSD symptoms, concussion/MTBI was not associated with postdeployment symptoms or outcomes. Time 1 PTSD symptoms more strongly predicted postdeployment symptoms and outcomes than did concussion/MTBI history.

Conclusions: Although combat-related PTSD was strongly associated with postconcussive symptoms and psychosocial outcomes 1 year after soldiers returned from Iraq, there was little evidence of a long-term negative impact of concussion/MTBI history on these outcomes after accounting for PTSD. These findings and the 2-fold increase in reports of deployment-related concussion/MTBI history have important implications for screening and treatment.

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NEARLY 2 MILLION TROOPS have been deployed to Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) since 2001. High levels of combat exposure have been documented among OEF/OIF–deployed soldiers, with increased risk of blast exposure and injury and development of postdeployment mental and physical health problems.[1-3] Traumatic brain injury (TBI), especially due to improvised explosive devices, has been described as a "signature injury" of OEF/OIF.[4] Most TBIs sustained in OEF/OIF are mild (MTBI), also known as concussion, and characterized by brief loss or alteration of consciousness and/or brief periods of posttraumatic amnesia.[5] The incidence of concussion/MTBI sustained in current conflicts is unclear, in part because of varying screening strategies.[6] However, initial estimates suggest that from 11% to 22% of OEF/OIF soldiers may sustain concussion/MTBI during their service.[3,7]

There has also been concern about rates of combat-related posttraumatic stress disorder (PTSD) among returning OEF/OIF veterans.[8] Consistent with estimates from previous conflicts,[9] the prevalence of PTSD

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among military personnel deployed to OEF/OIF generally ranges from 10% to 17%.[8] Rates of PTSD are even higher among OEF/OIF veterans receiving health care from the Department of Veterans Affairs (VA).[10] In a recent review, rates of PTSD among OEF/OIF soldiers with a history of concussion/MTBI ranged from 33% to 39%.[11]

There is widespread concern within the US Department of Defense (DOD) and the VA about the long-term impact of concussion/MTBI and PTSD in the lives of returning OEF/OIF veterans.[12-14] The DOD and the VA have implemented large-scale postdeployment screening programs to identify returning service members and veterans with potential health problems, including concussion/MTBI and PTSD, that may require further evaluation and treatment.[15] Although a substantial body of literature has shown that combat-related PTSD is associated with psychological and physical comorbidities and long-term disability,[16-20] less is known about deployment-related concussion/MTBI.[5]

Much of our knowledge of concussion/MTBI comes from studies within the civilian sector, such as sports-related concussion/MTBI.[21,22] One consistent finding from this literature is that most civilians who sustain concussion/MTBI recover completely by 1 week to 3 months after injury,[23-25] with a small minority (1%-5%) complaining of persistent postconcussive symptoms (PCSs) months or years after injury.[26] This minority express a variety of physical (eg, headache, tinnitus), emotional (eg, irritability), or cognitive symptoms (eg, diminished concentration or memory ability) that are directly attributed to the previous concussion.[27] However, PCSs are highly nonspecific. Researchers have shown that PCSs are encountered frequently among healthy adults[28,29] and clinical groups without a history of concussion/MTBI. Postconcussive symptoms also significantly overlap with depression,[30] PTSD,[31] and chronic pain.[32]

Given that deployment-related concussion/MTBI is often sustained in the context of potentially traumatizing events within the war zone (eg, life-threatening blast), it is not surprising that concussion/MTBI is associated with comorbid PTSD.[3,33-35] However, debate continues regarding the relationships among concussion/MTBI, PTSD, and PCSs. In a cross-sectional study of OIF soldiers, Hoge and colleagues[3] found that a history of concussion/MTBI was associated with more postconcussive and somatic symptoms, poorer general health, and more work days missed 3 to 4 months after deployment. However, after controlling for PTSD and depression, concussion/MTBI was no longer associated with these outcomes (except headache). Similarly, Schneiderman and colleagues[33] reported that PTSD was the strongest factor associated with PCSs, even after excluding overlapping symptoms. Marx and colleagues[34] reported that PTSD symptoms, but not deployment-related head injury, were associated with neuropsychological deficit (reduced attention) after deployment. Finally, Pietrzak and colleagues[35] reported that PTSD mediated the relationship between concussion/MTBI and perceived health and psychosocial functioning. However, these studies, based on cross-sectional data, were unable to determine whether PTSD mediated or confounded the association between concussion/MTBI and postdeployment health outcomes. Mediation and confounding share the same statistical relationship in cross-sectional data but have potentially different implications for describing the causal relationship between variables. Mediation implies a temporal sequence from the risk factor (ie, concussion/MTBI) to the dependent variable (ie, postdeployment health outcomes) via a mediating variable (ie, PTSD), whereas confounding implies that the relationship between the risk factor (concussion/MTBI) and the dependent variable (postdeployment health outcomes) is noncausal and results from the fact that the true causal variable (PTSD) is independently associated with the risk factor and the dependent variable. Understanding the role of PTSD as mediating or confounding the statistical association between concussion/MTBI and postdeployment health outcomes has important implications for treatment.

Despite the focus of the DOD and VA on early identification of concussion/MTBI,[15] there are limited data on the functional impact of concussion/MTBI history among OEF/OIF veterans. It is currently unknown whether OEF/OIF service members who reported having sustained concussion/MTBI in theater will show a course of psychosocial adjustment similar to that documented within the civilian sector and what effect concussion/MTBI may have on veterans' psychosocial outcomes when comorbid with PTSD. Given the high levels of PTSD among OEF/OIF veterans with a history of concussion/MTBI, it is also imperative that we better understand the impact of PTSD and concussion/MTBI on postdeployment outcomes.

Using longitudinal data from a large panel of US National Guard soldiers deployed to Iraq who underwent assessment in theater (time 1) and 1 year after deployment (time 2), we evaluated the prevalence and comorbidity of concussion/MTBI and PTSD over time and the extent that concussion/MTBI sustained in theater, with and without PTSD, predicted soldiers' persisting PCSs, psychosocial functioning, physical health, and quality of life 1 year after deployment.

METHODS

STUDY SAMPLE AND DATA COLLECTION

In June 2007, 2677 soldiers from a US National Guard Brigade Combat Team completed a time 1 questionnaire 1 month before their return home from an extended 16-month combat deployment (March 2006 to July 2007) to Iraq.[36] The questionnaire inquired about deployment experiences, including exposure to deployment events that could potentially lead to concussion/MTBI and current psychiatric symptoms (PTSD and depression). The time 1 sample (68.5% of the entire Brigade Combat Team force) was recruited through redeployment transition briefings. During briefings, soldiers were given a packet containing an informed consent document, a questionnaire, and an envelope. To maintain confidentiality, soldiers were asked to seal their completed or uncompleted questionnaire in the envelope before returning it to the on-site military collaborator to ship (via Federal Express) to the research team for processing and analysis. Following military regulations, no compensation was provided to participants.

Of those surveyed at time 1, 1935 agreed to be invited to participate in future research. One year after deployment (time

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2), we mailed a follow-up questionnaire, a cover letter containing the elements of informed consent, and a $20 incentive to 1892 panel members (26 had untrackable addresses, 4 were temporarily away or incarcerated, 20 were redeployed, and 2 were deceased). A postcard reminder and 2 additional mailings were sent to nonresponders at 2-week intervals. Response rate was 50.4% (n=953). There was no difference between soldiers who did and did not return a time 2 questionnaire on reports at time 1 of in-theater blast exposure, PTSD symptoms, sex, or ethnicity. Panel members who did not complete the follow-up questionnaire were younger (mean [SD] age, 29.1 [7.7] vs 31.5 [8.3] years; $t_{2541}=-7.36$; $P<.001$), were more likely to be unmarried (62.3% vs 51.2%; $P<.001$), were more likely to be of enlisted rank (91.6% vs 86.6%; $P<.001$), and had lower levels of in-theater depression (mean [SD] scale scores, 8.53 [7.66] vs 9.28 [8.43]; $t_{2615}=2.25$; $P=.03$) compared with those who completed the follow-up questionnaire.

The study protocol was approved by the institutional review boards of the US Army, the University of Minnesota, the VA, and the Minnesota Army National Guard command.

IN-THEATER ASSESSMENT

Time 1 measures screened for blast exposure and concussion/MTBI sustained during deployment and for current symptoms of PTSD and depression. The following 3 items adapted from the Defense and Veterans Brain Injury Center screening tool were used[37]: (1) "Were you ever so close to a blast that you could feel the blast wave or afterward had trouble hearing or problems with attention or memory?" (2) "Did you have any injuries from a blast, bullet/shrapnel, vehicle crash, or fall?" and (3) "Did any injury cause you to be dazed/confused, 'see stars,' get knocked out, or lose consciousness?" Participants were categorized as having a history of in-theater concussion/MTBI if they endorsed injury with altered mental status or loss of consciousness (question 3).

Current in-theater PTSD symptoms were assessed using the 17-item self-report PTSD Checklist–Military (PCL-M).[38] Soldiers rated items corresponding to the *DSM-IV*[39] symptom criteria for PTSD on a 5-point scale in reference to the most stressful event experienced during deployment. Depressive symptoms were assessed using the Beck Depression Inventory II,[40] a widely used 21-item self-report scale. Higher scores on both measures indicate more severe symptoms. Basic background information, including sex, age, race/ethnicity, and rank, were also collected.

1-YEAR POSTDEPLOYMENT ASSESSMENT

At time 2, soldiers were again asked about their deployment-related experiences, including combat exposure, exposure to explosive blasts and injuries sustained during deployment, and history of in-theater concussion/MTBI. Combat exposure was quantified by a modified version of the combat experiences subscale of the Deployment Risk and Resilience Inventory[34,41,42] that assessed frequency of 15 combat events, with higher scores indicating greater levels of combat exposure. Exposure to deployment-related blasts, injuries, and history of in-theater concussion/MTBI were assessed using items from the Defense and Veterans Brain Injury Center screening tool.[37] Soldiers were asked whether they were injured during deployment, and those reporting injury were queried about common mechanisms (ie, fragment, bullet, vehicle, fall, blast, or other) of injuries. Soldiers were also asked whether any injuries resulted in altered consciousness with the following question: "Did any injury received while you were deployed result in any of the following: being dazed, confused, or 'seeing stars'; not remembering the injury; losing consciousness (knocked out) for less than a minute; losing consciousness for 1 to 20 minutes; or losing consciousness for longer than 20 minutes?" Participants were categorized at time 2 as having a history of in-theater concussion/MTBI if they endorsed injury and at least 1 item assessing altered mental status or loss of consciousness for less than 20 minutes. Postconcussive symptoms (ie, memory problems, balance problems, ringing in the ears, concentration problems, and irritability) were assessed independently from injury using the same 5 items reported by Hoge and colleagues.[3]

Current postdeployment PTSD symptoms were measured using the PCL-M. Participants were classified as having probable PTSD if they met *DSM-IV* symptom criteria on the PCL-M (reporting at least 1 intrusion symptom, 3 avoidance symptoms, and 2 hyperarousal symptoms at moderate levels) and obtained a total score of at least 50.[43,44] These criteria have been previously used with military personnel deployed to OEF/OIF. Current postdeployment depressive symptoms were assessed with the Beck Depression Inventory II, and a cutoff of 20 was used to classify probable depression.[40] Current problematic alcohol use was assessed using the 10-item Alcohol Use Disorders Identification Test,[45,46] which measures quantity/frequency of alcohol use and degree of hazardous drinking, with higher scores indicative of problematic drinking. Generalized somatic symptoms were assessed using the Patient Health Questionnaire 15-item somatic symptom severity scale,[47] with higher scores indicating greater number and severity of nonspecific somatic symptoms. Social adjustment was assessed with the Social Adjustment Scale Self-report,[48] which evaluates perceived functional status across domains (eg, work outside the home, social and leisure activities), with higher scores reflecting greater impairment. The 26-item World Health Organization Quality of Life–Brief Scale[49] was used to evaluate perceived quality of life in the areas of physical health and environment, with higher scores reflecting better perceived quality of life.

STATISTICAL ANALYSES

Based on soldiers' report of time 1 concussion/MTBI and time 2 probable PTSD, each participant was categorized into 1 of the following 4 groups: (1) those who reported no concussion/MTBI or PTSD (control group), (2) those who reported concussion/MTBI but no probable PTSD (MTBI-only group), (3) those with probable PTSD but no report of concussion/MTBI (PTSD-only group), and (4) those who reported concussion/MTBI and probable PTSD (comorbid MTBI-PTSD group). One participant who reported loss of consciousness for 20 minutes or greater was excluded from analysis because it could not be verified that the TBI sustained was no more than mild in severity. Groups were compared on sociodemographic variables, mechanism of injury, postdeployment PCSs, psychiatric and somatic symptoms, quality of life, and social functioning using Pearson χ^2 analysis, analysis of variance, and 2-tailed independent-sample t tests, depending on the variable's level of measurement. For variables with a statistically significant overall F test, post hoc analyses were conducted using a series of logistic regressions in which each psychosocial variable was regressed on each MTBI/PTSD group. Analyses are reported for the MTBI-only vs control, PTSD-only vs control, PTSD-only vs MTBI-only, and comorbid MTBI-PTSD vs PTSD-only groups. Symptoms of PTSD can still be present in individuals not meeting full screening criteria for the disorder, and these symptoms can complicate interpretation of the effects of MTBI.[3] Therefore, comparisons of the MTBI-only vs control groups were conducted in the following 2 ways: (1) without controlling for level of time 2 PTSD symptoms, and (2) controlling for time 2 PTSD symptoms (time 2 PCL-M total score). To examine the

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Table 1. Demographic Characteristics and Deployment Experiences by In-Theater MTBI and Postdeployment PTSD Status[a]

Postdeployment Sample Characteristic	Group: Control (n=748)	MTBI-Only (n=60)	PTSD-Only (n=103)	Comorbid PTSD-MTBI (n=26)	All Participants (N=937)	*P* Value
Age, mean (SD), y	32.7 (8.2)	31.0 (8.0)	33.5 (9.3)	31.4 (7.0)	32.7 (8.3)	.24
Male sex	688 (92.0)	58 (96.7)	95 (92.2)	26 (100.0)	**867** (92.5)	.35
Married	378 (50.5)	27 (45.0)	44 (42.7)	11 (42.3)	**460** (49.1)	.37
White	634 (87.8)	53 (88.3)	80 (80.8)	23 (88.5)	**790** (87.1)	.27
≤High school education	151 (20.2)	13 (21.7)	29 (28.2)	4 (15.4)	**197** (21.0)	.27
Rank						<.001
Enlisted	628 (84.3)	53 (88.3)	102 (100.0)	24 (92.3)	**807** (86.5)	
Officer	117 (15.7)	7 (11.7)	0	2 (7.7)	**126** (13.5)	
No. of previous deployments						.25
0	386 (51.6)	33 (55.0)	58 (56.3)	10 (38.5)	**487** (52.0)	
1	326 (43.6)	21 (35.0)	40 (38.8)	13 (50.0)	**400** (42.7)	
≥2	36 (4.8)	6 (10.0)	5 (4.9)	3 (11.5)	**50** (5.3)	
Rate of injury by mechanism[b]						
Fragment	10 (1.3)	11 (18.3)	3 (2.9)	4 (15.4)	**28** (3.0)	<.001
Bullet	1 (0.1)	1 (1.7)	0	0	**2** (0.2)	.09
Vehicular	53 (7.1)	12 (20.0)	8 (7.8)	6 (23.1)	**79** (8.4)	<.001
Fall	75 (10.0)	6 (10.0)	25 (24.3)	9 (34.6)	**115** (12.3)	<.001
Blast	106 (14.2)	42 (70.0)	37 (35.9)	21 (80.8)	**206** (22.0)	<.001
Other	153 (20.5)	11 (18.3)	28 (27.2)	4 (15.4)	**196** (20.9)	.35

Abbreviations: MTBI, mild traumatic brain injury; PTSD, posttraumatic stress disorder.
[a]The sample size varies slightly across observations because of missing data. Groups are based on concussion/MTBI reported at time 1 and probable PTSD reported at time 2. Unless otherwise indicated, data are expressed as number (percentage) of participants. Percentages have been rounded and may not total 100.
[b]Soldiers were asked after deployment whether they had sustained any injury during deployment. Soldiers in the control and PTSD-only groups reported injury but did not endorse concussion/MTBI.

impact of MTBI and PTSD on postdeployment outcomes, we calculated odds ratios, 99% confidence intervals, and *P* values using multivariate logistic regression. All continuously distributed variables were converted to *z* scores before entry into the regression models. To examine the potential confounding role of in-theater PTSD symptoms (time 1 PCL-M total score) on the link between time 1 MTBI status and time 2 outcomes, we conducted a series of regression analyses regressing each outcome variable on MTBI in step 1 and then entering time 1 PCL-M total score in step 2. To protect against type I error, the α value was set at .01. All analyses were conducted using SPSS statistical software, version 17 (SPSS, Inc, Chicago, Illinois).

RESULTS

SAMPLE CHARACTERISTICS AND DEPLOYMENT EXPERIENCES

Demographic characteristics overall and by MTBI/PTSD status groups based on concussion/MTBI reported at time 1 and probable PTSD reported at time 2 are shown in **Table 1**. Consistent with demographics of infantry soldiers deployed to Iraq,[1,3] overall, 92.5% were male, 46.4% were younger than 30 years, and 86.5% were enlisted rank. Enlisted soldiers were more likely to have screening results positive for PTSD at time 2 (χ^2_1=17.88; 933 individuals responding; $P<.001$), whereas officers were more likely to be in the control group (χ^2_1=15.39; 933 individuals responding; $P<.001$). Nearly half reported having served 1 or more previous OEF/OIF deployments. Overall, 87.9% reported participating in combat missions or patrols, 98.3% reported receiving incoming small-arms fire, and 76.1% were attacked by enemy (data not shown). Rates of injury by various mechanisms reported by soldiers are shown in Table 1. Blast exposure was the most frequent mechanism listed by soldiers reporting deployment-related concussion/MTBI at time 1.

RATES OF IN-THEATER AND POSTDEPLOYMENT PSYCHIATRIC SYMPTOMS

At time 1, 7.6% of the overall panel met screening criteria for probable PTSD and 9.3% had screening results positive for probable depression; rates of probable PTSD (13.7%; χ^2_1=19.84; 941 individuals responding; $P<.001$) and depression (18.2%; χ^2_1=30.91; 931 individuals responding; $P<.001$) increased at time 2. Change in PTSD symptoms (time 1 to time 2) was no different for those who reported concussion/MTBI at time 1 compared with those who did not ($F_{1,932}$=2.36; P=.13). At time 2, overall, 41.9% had screening results positive for problematic drinking and 28.5% endorsed clinically significant levels of nonspecific somatic complaints.

REPORTS OF CONCUSSION/MTBI IN THEATER AND AFTER DEPLOYMENT

We examined the prevalence of deployment-related concussion/MTBI based on soldiers' reports in theater compared with after deployment. The rates of self-reported concussion/MTBI sustained in Iraq were 9.2% at time 1 and 22.0% at time 2. Of those reporting a history of concussion/MTBI at time 1, 30.2% had probable PTSD at time 2, whereas 30.4% of those reporting concussion/MTBI at time 2 had probable PTSD at time 2.

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Table 2. Postdeployment Psychosocial Outcomes by In-Theater MTBI and Postdeployment PTSD Status[a]

Outcome Measured at Time 2	Group: Control (n=748)	MTBI-Only (n=60)	PTSD-Only (n=103)	Comorbid PTSD-MTBI (n=26)
PCS				
Memory problems	443 (59.5)	47 (78.3)	98 (97.0)	25 (96.2)
Balance problems	169 (22.7)	20 (33.3)	78 (75.7)	16 (61.5)
Ringing in ears	426 (57.3)	46 (76.7)	90 (89.1)	25 (96.2)
Concentration problems	480 (64.3)	48 (80.0)	101 (98.1)	26 (100.0)
Irritability	476 (63.8)	50 (83.3)	102 (99.0)	26 (100.0)
PTSD symptoms (total PCL-M score), mean (SD)	29.3 (9.2)	34.3 (9.4)	62.5 (8.1)	63.1 (7.3)
Reexperiencing symptoms	7.6 (2.7)	9.0 (2.9)	16.8 (3.7)	17.0 (3.7)
Avoidance symptoms	11.5 (4.3)	12.8 (3.8)	25.3 (4.1)	25.4 (3.4)
Arousal symptoms	10.1 (3.7)	12.4 (4.3)	20.4 (2.7)	20.7 (2.6)
BDI-II, mean (SD) score	8.8 (7.2)	11.4 (8.5)	25.0 (8.9)	25.5 (8.7)
PHQ-15, mean (SD) score	9.5 (5.5)	11.6 (5.9)	19.1 (5.0)	17.2 (5.9)
Stomach pain	254 (34.0)	30 (50.0)	74 (72.5)	19 (73.1)
Back pain	606 (81.2)	53 (88.3)	97 (96.0)	26 (100.0)
Pain in arms, legs, or joints	583 (78.4)	53 (88.3)	99 (98.0)	23 (88.5)
Headaches	478 (64.1)	46 (76.7)	95 (93.1)	25 (96.2)
Chest pain	194 (26.0)	21 (35.0)	64 (62.1)	15 (60.0)
Dizziness	210 (28.2)	30 (50.8)	76 (73.8)	17 (65.4)
Fainting spells	34 (4.6)	2 (3.4)	23 (22.3)	6 (23.1)
Feeling your heart race or pound	322 (43.1)	35 (59.3)	92 (91.1)	20 (76.9)
Shortness of breath	234 (31.4)	21 (35.6)	77 (74.8)	19 (73.1)
Pain or problems during sex	110 (14.8)	13 (21.7)	40 (39.6)	8 (30.8)
Constipation, loose bowels, or diarrhea	332 (44.7)	33 (55.0)	82 (79.6)	20 (76.9)
Nausea, gas, or indigestion	368 (49.4)	31 (52.5)	85 (82.5)	19 (73.1)
Feeling tired or having low energy	573 (76.8)	48 (81.4)	102 (99.0)	24 (92.3)
Sleep disturbance	450 (60.2)	42 (70.0)	101 (98.1)	24 (92.3)
AUDIT, mean (SD) score	7.2 (5.4)	9.8 (7.1)	12.5 (9.6)	15.2 (9.3)
SAS-SR, mean (SD) score	2.1 (0.4)	2.2 (0.4)	2.9 (0.4)	2.9 (0.4)
WHOQOL-BREF, mean (SD) score				
Physical health subscale	12.8 (1.6)	12.6 (1.7)	11.0 (1.7)	11.3 (2.2)
Environment subscale	15.0 (2.2)	14.3 (2.5)	12.1 (2.6)	12.8 (2.7)

Abbreviations: AUDIT, Alcohol Use Disorders Identification Test; BDI-II, Beck Depression Inventory-II; MTBI, mild traumatic brain injury; PCL-M, PTSD (posttraumatic stress disorder) Checklist–Military Version; PCS, postconcussive symptom; PHQ-15, Patient Health Questionnaire 15-item somatic symptom severity scale; SAS-SR, Social Adjustment Scale Self-report; WHOQOL-BREF, World Health Organization Quality of Life–Brief Scale.

[a]The sample size varies slightly across observations because of missing data. Unless otherwise indicated, data are expressed as number (percentage) of participants. Groups are based on concussion/MTBI reported at time 1 and probable PTSD reported at time 2.

IMPACT OF CONCUSSION/MTBI AND PTSD ON POSTDEPLOYMENT PCSs

Next, we examined report of PCSs at time 2 by MTBI/PTSD status groups based on time 1 concussion/MTBI and time 2 probable PTSD (**Table 2**). Regardless of whether soldiers reported sustaining concussion/MTBI in Iraq, self-report of time 2 PCSs was common. Results of χ^2 analyses found differences between the groups for all PCSs at $P<.001$. As shown in **Table 3**, memory problems, ringing in the ears, and irritability were more common in the MTBI-only group than in the control group; however, once we controlled for time 2 PCL-M total score, differences between the MTBI-only group and control group were no longer significant. All time 2 PCSs were more common in the PTSD-only group compared with the control group, whereas postdeployment memory problems, balance problems, difficulty concentrating, and irritability were all more common in the PTSD-only group compared with the MTBI-only group (Table 3). There were no differences in these self-reported postdeployment symptoms between the comorbid MTBI-PTSD and PTSD-only groups.

We also examined the potential confounding role of in-theater PTSD symptoms (time 1 PCL-M total score) in explaining the association between time 1 concussion/MTBI and time 2 PCSs. Time 1 PCL-M total score was a more potent predictor than time 1 MTBI status of all postdeployment PCSs (**Table 4**). Balance and concentration problems were no longer associated with time 1 MTBI status after time 1 PCL-M total score was entered into the model. These findings did not change on the basis of time 1 reports of blast exposure (data not shown). In addition, in a multivariate regression, we regressed the time 2 total PCSs score on time 1 MTBI status and time 1 PCL-M total score. The variance explained by time 1 PCL-M total score ($r^2=0.179$) was substantially larger than that explained by time 1 MTBI status ($r^2=0.036$), although concussion/MTBI remained a significant predictor.

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Table 3. ORs for Postdeployment Psychosocial Outcomes by In-Theater MTBI and Postdeployment PTSD Status[a]

Postdeployment Outcome Measured at Time 2	Group, OR (99% CI)				
	MTBI-Only vs Control				
	Unadjusted[b]	Adjusted for PTSD[b]	PTSD-Only vs Control[b]	PTSD-Only vs MTBI-Only[b]	Comorbid MTBI-PTSD vs PTSD-Only[b]
PCS					
Memory problems	2.47 (1.08-5.65)[c]	1.65 (0.66-4.10)	22.27 (4.86-102.02)[c]	9.04 (1.63-50.06)[c]	0.77 (0.04-15.84)
Balance problems	1.70 (0.81-3.57)	1.11 (0.50-2.49)	10.63 (5.64-20.04)[c]	6.24 (2.48-15.67)[c]	0.51 (0.16-1.70)
Ringing in ears	2.45 (1.09-5.51)[c]	1.86 (0.80-4.32)	6.11 (2.63-14.21)[c]	2.49 (0.80-7.77)	3.06 (0.20-47.93)
Concentration problems	2.23 (0.95-5.23)	1.20 (0.43-3.35)	28.09 (4.42-178.62)[c]	12.63 (1.68-95.03)[c]	[d]
Irritability	2.84 (1.14-7.07)[c]	1.77 (0.63-4.98)	57.86 (4.32-775.75)[c]	20.40 (1.32-315.27)[c]	[d]
BDI-II	1.47 (0.99-2.17)[c]	1.01 (0.58-1.77)	7.48 (4.75-11.77)[c]	6.18 (2.92-13.09)[c]	1.07 (0.58-1.94)
PHQ-15	1.54 (1.05-2.27)[c]	1.12 (0.68-1.85)	7.10 (4.53-11.13)[c]	4.43 (2.35-8.34)[c]	0.66 (0.34-1.29)
Stomach pain	1.94 (0.97-3.88)[c]	1.49 (0.72-3.07)	5.12 (2.80-9.38)[c]	2.64 (1.10-6.35)[c]	1.03 (0.29-3.67)
Back pain	1.75 (0.60-5.07)	1.25 (0.42-3.75)	5.60 (1.47-21.32)[c]	3.20 (0.60-17.07)	[d]
Pain in arms, legs, or joints	2.09 (0.72-6.04)	1.50 (0.50-4.48)	13.67 (2.14-87.28)[c]	6.54 (0.79-53.99)	0.16 (0.01-1.75)
Headaches	1.84 (0.82-4.14)	1.33 (0.57-3.12)	7.61 (2.72-21.27)[c]	4.13 (1.15-14.84)[c]	1.84 (0.11-30.72)
Chest pain	1.53 (0.74-3.18)	1.08 (0.50-2.34)	4.67 (2.65-8.22)[c]	3.05 (1.28-7.29)[c]	0.91 (0.28-2.96)
Dizziness	2.64 (1.31-5.32)[c]	1.95 (0.92-4.13)	7.17 (3.88-13.25)[c]	2.72 (1.12-6.59)[c]	0.67 (0.20-2.25)
Fainting spells	0.74 (0.11-4.95)	0.52 (0.08-3.63)	6.02 (2.82-12.86)[c]	8.19 (1.17-57.63)[c]	1.04 (0.27-4.01)
Feeling your heart race or pound	1.93 (0.95-3.91)	1.25 (0.56-2.78)	13.49 (5.38-33.84)[c]	7.01 (2.27-21.68)[c]	0.33 (0.07-1.46)
Shortness of breath	1.21 (0.58-2.50)	0.79 (0.36-1.72)	6.47 (3.48-12.01)[c]	5.36 (2.15-13.34)[c]	0.92 (0.26-3.30)
Pain or problems during sex	1.59 (0.68-3.72)	1.14 (0.47-2.76)	3.77 (2.10-6.79)[c]	2.37 (0.91-6.21)	0.68 (0.20-2.28)
Constipation, loose bowels, or diarrhea	1.51 (0.76-3.03)	1.17 (0.57-2.41)	4.83 (2.50-9.33)[c]	3.20 (1.28-8.01)[c]	0.85 (0.22-3.31)
Nausea, gas, or indigestion	1.13 (0.57-2.28)	0.81 (0.39-1.70)	4.84 (2.42-9.69)[c]	4.27 (1.65-11.00)[c]	0.58 (0.15-2.15)
Feeling tired or having low energy	1.32 (0.54-3.21)	0.80 (0.31-2.09)	30.80 (2.29-413.82)[c]	23.38 (1.53-357.65)[c]	0.12 (0.01-2.91)
Sleep disturbance	1.55 (0.73-3.27)	0.88 (0.37-2.09)	33.44 (5.26-212.55)[c]	21.64 (3.00-156.33)[c]	0.24 (0.02-3.34)
AUDIT	1.53 (1.09-2.15)[c]	1.35 (0.95-1.91)	1.97 (1.54-2.51)[c]	1.28 (0.91-1.80)	1.22 (0.83-1.78)
SAS-SR	1.30 (0.87-1.95)	0.86 (0.52-1.42)	8.07 (5.06-12.85)[c]	6.20 (3.02-12.72)[c]	1.07 (0.55-2.07)
WHOQOL-BREF					
Physical health subscale	0.82 (0.57-1.18)	1.00 (0.67-1.49)	0.33 (0.25-0.45)[c]	0.39 (0.24-0.65)[c]	1.17 (0.69-1.98)
Environment subscale	0.75 (0.52-1.08)	0.92 (0.62-1.37)	0.30 (0.22-0.41)[c]	0.40 (0.24-0.67)[c]	1.32 (0.75-2.33)

Abbreviations: CI, confidence interval; OR, odds ratio. For other abbreviations, see Table 2.
[a] Groups based on concussion/MTBI reported at time 1 and probable PTSD reported at time 2.
[b] Indicates reference group.
[c] $P < .01$.
[d] Indicates ORs could not be calculated because of near-unanimous endorsement of symptom in both groups.

IMPACT OF CONCUSSION/MTBI AND PTSD ON POSTDEPLOYMENT PSYCHOSOCIAL OUTCOMES

Group differences in postdeployment psychosocial outcomes are given in Table 2. Overall *F* tests indicated group differences for all postdeployment outcomes at the $P < .01$ level. As shown in Table 3, after adjusting for time 2 PCL-M total score, there were no differences between the MTBI-only and control groups on time 2 measures of depression, problematic drinking, social functioning, and quality of life (Table 3). In the unadjusted analysis, the MTBI-only group reported higher levels of nonspecific somatic complaints (Patient Health Questionnaire 15-item somatic symptom severity scale total score), stomach pain, and dizziness. However, after adjusting for time 2 PCL-M total, these associations were no longer significant. Similarly, there were no differences between the comorbid MTBI-PTSD and PTSD-only groups on any of the postdeployment psychosocial outcomes. The PTSD-only group reported significantly greater levels of all postdeployment outcomes than the control group. Compared with the MTBI-only group, the PTSD-only group reported higher levels of depression and nonspecific somatic complaints (except back pain; pain in arms, legs or joints; and pain or problems during sex) and lower social functioning and quality of life.

Results of analyses examining the potential confounding role of in-theater PTSD symptoms in explaining the association between concussion/MTBI and postdeployment outcomes are shown in **Table 5**. After accounting for time 1 PCL-M total score, concussion/MTBI reported at time 1 no longer predicted time 2 depressive symptoms, nonspecific somatic complaints, social functioning, or quality of life. These findings did not change on the basis of time 1 reports of blast exposure (data not shown).

Finally, because PTSD symptoms overlap with PCSs, we conducted 2 additional analyses. First, we reanalyzed group comparisons on the basis of time 1 (rather than time 2) PTSD status. This did not change the pattern of results or demonstrate additional effects of concussion/MTBI except that time 1 concussion/MTBI was associated with higher rates of postdeployment problematic drinking (64.1%) compared with the control group (38.6%). Second, we reanalyzed group comparisons adjusting for time 2 PTSD symptoms using a PTSD index that excluded symptoms of irritability and diffi-

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Table 4. Logistic Regression Results for the Effects of Time 1 MTBI Status and Time 1 PTSD Symptoms on Time 2 PCSs

Postdeployment Outcome Measured at Time 2	Coefficient, β (SE)	Wald χ^2 Value	*P* Value	OR (99% CI)
Memory problems				
Step 1 in-theater MTBI status	1.07 (0.30)	12.66	<.001	2.92 (1.34-6.33)
Step 2				
In-theater MTBI status	0.78 (0.31)	6.30	.01	2.17 (0.98-4.82)
In-theater PTSD symptoms	0.60 (0.09)	42.20	<.001	1.83 (1.44-2.32)
Balance problems				
Step 1 in-theater MTBI status	0.57 (0.23)	6.13	.01	1.77 (0.98-3.22)
Step 2				
In-theater MTBI status	0.23 (0.25)	0.88	.35	1.26 (0.67-2.37)
In-theater PTSD symptoms	0.61 (0.08)	58.90	<.001	1.84 (1.50-2.25)
Ringing in ears				
Step 1 in-theater MTBI status	1.11 (0.29)	14.38	<.001	3.04 (1.43-6.45)
Step 2				
In-theater MTBI status	0.85 (0.30)	8.04	.01	2.34 (1.08-5.07)
In-theater PTSD symptoms	0.52 (0.09)	35.61	<.001	1.68 (1.34-2.10)
Concentration problems				
Step 1 in-theater MTBI status	1.05 (0.32)	10.75	.001	2.85 (1.25-6.51)
Step 2				
In-theater MTBI status	0.63 (0.34)	3.56	.06	1.88 (0.79-4.45)
In-theater PTSD symptoms	0.95 (0.11)	69.72	<.001	2.57 (1.92-3.44)
Irritability				
Step 1 in-theater MTBI status	1.28 (0.34)	13.73	<.001	3.58 (1.48-8.70)
Step 2				
In-theater MTBI status	0.91 (0.36)	6.60	.01	2.49 (1.00-6.22)
In-theater PTSD symptoms	0.82 (0.11)	58.48	<.001	2.27 (1.72-2.99)

Abbreviations: CI, confidence interval; MTBI, mild traumatic brain injury; OR, odds ratio; PCSs, postconcussive symptoms; PTSD, posttraumatic stress disorder.

culty concentrating (time 2 PCL-M total score minus PCL-M items 14 and 15). Again, there was no change in the pattern or magnitude of results.

COMMENT

This is, to our knowledge, the first study to assess soldiers' report of concussion/MTBI while in theater and to longitudinally examine the impact of concussion/MTBI and PTSD on psychosocial outcomes 1 year after soldiers' return from combat deployment. Consistent with other reports, this cohort of National Guard soldiers reported high levels of combat exposure.[1,50] Despite this, the prevalence of concussion/MTBI in theater was 9.2%, a rate lower than previously documented among military personnel returning from OEF/OIF.[3,7] It is possible this Brigade Combat Team may have been exposed to less combat than regular Army or Marines and may not be representative of all deployed military personnel. However, the lower rate may also be due to the timing of assessments. Other studies assessing concussion/MTBI conducted after soldiers have returned home have documented higher rates of concussion/MTBI. Similarly, at 1 year after deployment, we found that reports of concussion/MTBI history more than doubled (22.0%) among the longitudinal panel. Because soldiers returned home about 1 month after the in-theater assessment, it is unlikely that the doubling in reported concussion/MTBI after deployment was caused by events taking place between assessment and departure from Iraq. Differences in rates of reported MTBI could be the result of recall bias, poor reliability of the instrument, or different contexts for assessment. Over time, retrospective recall of combat events and history of concussion/MTBI may be influenced by current symptoms of distress, attributions about current psychosocial difficulties, and secondary gain.[51,52] For some returning soldiers, for example, postdeployment endorsement of concussion/MTBI may reflect a recommendation to seek service connection for injuries sustained during combat. Considering that TBI screening instruments similar to those administered herein, although widely used, have unknown psychometric properties,[53] it is also possible that the discrepancy is partly a reflection of the reliability of the screening questions. Alternatively, while in theater, soldiers may minimize reports of concussion/MTBI history to remain with their units, live up to perceived expectations of superiors and peers, and ensure health concerns do not delay return home during demobilization. On return from deployment, soldiers may feel at liberty to express health concerns and disclose events that may have contributed to concussion/MTBI. Additional research is needed to identify factors accounting for discrepant reports of concussion/MTBI over time.

One important finding was the lack of evidence of an independent impact of concussion/MTBI on soldiers' postdeployment psychosocial outcomes. After accounting for PTSD, we found that a history of concussion/MTBI alone was not associated with postdeployment PCSs, depression, problematic drinking, nonspecific somatic complaints, social adjustment, or quality of life. These findings, which are consistent with those from civilian and military studies, suggest that a history of concussion/

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Table 5. Multiple Linear Regression Results for the Effects of Time 1 MTBI Status and Time 1 PTSD Symptoms on Time 2 PCSs and Psychosocial Outcomes

Postdeployment Outcome Measured at Time 2	Unstandardized Coefficient, β (SE)	Standardized Coefficient, β	*P* Value	R^2 Value
PCSs				
Step 1 in-theater MTBI status	0.609 (0.104)	0.189	<.001	0.036
Step 2				0.215
In-theater MTBI status	0.348 (0.095)	0.108	<.001	
In-theater PTSD symptoms	0.425 (0.029)	0.431	<.001	
BDI-II				
Step 1 in-theater MTBI status	4.960 (1.053)	0.153	<.001	0.023
Step 2				0.252
In-theater MTBI status	2.042 (0.939)	0.063	.03	
In-theater PTSD symptoms	0.388 (0.023)	0.486	<.001	
PHQ-15				
Step 1 in-theater MTBI status	2.709 (0.708)	0.124	<.001	0.015
Step 2				0.187
In-theater MTBI status	0.992 (0.655)	0.046	.13	
In-theater PTSD symptoms	0.227 (0.016)	0.422	<.001	
AUDIT				
Step 1 in-theater MTBI status	3.530 (0.734)	0.156	<.001	0.024
Step 2				0.060
In-theater MTBI status	2.719 (0.734)	0.120	<.001	
In-theater PTSD symptoms	0.107 (0.018)	0.191	<.001	
SAS-SR				
Step 1 in-theater MTBI status	0.200 (0.050)	0.129	<.001	0.017
Step 2				0.238
In-theater MTBI status	0.061 (0.045)	0.040	.17	
In-theater PTSD symptoms	0.018 (0.001)	0.479	<.001	
WHOQOL-BREF physical health subscale				
Step 1 in-theater MTBI status	−0.463 (0.193)	−0.078	.02	0.006
Step 2				0.100
In-theater MTBI status	−0.119 (0.187)	−0.020	.53	
In-theater PTSD symptoms	−0.045 (0.005)	−0.312	<.001	
WHOQOL-BREF environment subscale				
Step 1 in-theater MTBI status	−0.750 (0.281)	−0.087	.008	0.008
Step 2				0.104
In-theater MTBI status	−0.243 (0.272)	−0.028	.37	
In-theater PTSD symptoms	−0.067 (0.007)	−0.316	<.001	

Abbreviations: See Table 2.

MTBI during deployment does not result in significant postdeployment health effects that are independent from PTSD. However, this study did not quantify exposure to concussion/MTBI events during deployment and cannot address whether repeated concussion/MTBI may be associated with poorer postdeployment outcomes than single concussions. Similarly, this study did not address the impact of moderate to severe TBI on postdeployment outcomes, which is clinically distinct from concussion/MTBI.[26,54]

Findings support a large body of literature showing that PTSD can be a pernicious condition associated with other psychiatric problems and significant disruptions in social functioning and quality of life. The prevalence of PTSD among National Guard soldiers in this longitudinal panel was similar to that found in other studies using similar methods; however, there has been significant variability in PTSD prevalence across studies.[8] During a 1-year period, the rates of PTSD and depression in this panel significantly increased nearly 2-fold. Although there have been few longitudinal reports of soldiers' postdeployment mental health, results are consistent with those of other researchers who have found increased symptom reporting over time.[55] The rate of probable PTSD (30%) among those with a history of concussion/MTBI was similar to that of past reports.[11]

Postconcussive symptoms were commonly reported by respondents in this study. Although PCSs were more commonly reported by soldiers who experienced concussion/MTBI than those without a history of concussion/MTBI, this difference was no longer statistically significant once postdeployment PTSD symptoms were accounted for. These findings are consistent with other recent reports that PCSs are common among military personnel returning from Iraq but that such symptoms are not specific to concussion/MTBI.[56] This study adds to a growing body of literature showing that PTSD largely explains the relationship between history of concussion/MTBI and postdeployment PCSs.[3,33-35] Symptoms of PTSD, whether they were reported at time 1 or time 2, were more strongly associated with postdeployment PCSs than with concussion/MTBI history, suggesting that PTSD confounds the apparent association between concussion/MTBI and PCSs. Moreover, the label of "concussion/MTBI" as measured by screening questions used within the VA and DOD was associated with a number of non-

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specific symptoms unrelated to head injury that reflect generalized physiological effects of PTSD and other postdeployment health outcomes. Numerous studies have shown that PTSD is associated with generalized health problems.[57,58]

This study had several strengths, including its large sample of National Guard soldiers and longitudinal assessment of concussion/MTBI and PTSD. In terms of limitations, participants were self-selected from a single brigade combat team deployed to Iraq during a constrained period. Thus, results may not be generalizable to all military personnel deployed to Iraq. Although we obtained follow-up data from 50% of the original panel—a response rate similar to other studies of OEF/OIF veterans[33,59]—postdeployment findings may have been influenced by response biases. However, analyses of those who did and did not complete a follow-up questionnaire showed few demographic differences and no differences in reports of blast exposure and PTSD symptoms while in Iraq. Because we focused on deployment-related concussion/MTBI, we cannot ascertain that those classified as having no MTBI did not sustain a concussion before or during the year after deployment. The number of soldiers investigated in theater necessitated the use of self-report measures of concussion/MTBI history, PTSD, and other psychosocial outcomes. However, our findings suggest that self-report measures of MTBI history may have limited reliability, and future studies should incorporate objective military records to verify self-reports.

Nevertheless, results of this study have important implications for policymakers and clinicians. Postdeployment TBI screening policy has been based on widespread concern that concussion/MTBI may result in long-term disability and the assumption that a causal link has been established between a history of concussion/MTBI and postdeployment problems.[54] As a result, the VA has adopted a broad approach to TBI screening to ensure that veterans with histories of concussion do not go undetected.[6] However, our results suggest that screening for concussion/MTBI does not accurately identify veterans in need of help. This approach may actually have an iatrogenic effect on certain veterans who complete the TBI screening process. Research has shown that introducing the idea of previous concussive injury may in itself lead to a misattribution of symptoms, a concept known as "expectation as etiology."[60] By bringing attention to a previous concussion, veterans may develop a false expectation that current symptoms are caused by the past injury, when, in fact, they may be more attributable to non–concussion-related factors, such as PTSD, pain, sleep disturbance, or life stress.[6] Although we cannot conclude from these findings that current screening initiatives are causing unintended consequences, veterans' misattribution of postdeployment symptoms to concussion/MTBI may pose a significant barrier to accessing appropriate evidence-based treatment and hinder recovery. Finding a 2-fold increase in self-reported MTBI history after deployment while using the same clinical definition and screening questions adopted by the DOD and VA coupled with the finding that PTSD was more strongly predictive of postdeployment PCSs and psychosocial outcomes than MTBI status raises concerns about current screening practices and policy. Current DOD and VA screening programs that use instruments such as those used in this study should be reexamined in light of these findings.

Consistent with the larger civilian literature showing that most people recover quickly after concussion/MTBI and do not develop long-term psychosocial problems, the present study is the first, to our knowledge, to show that a history of concussion/MTBI alone does not contribute to long-term impairments in the health and well-being of OIF veterans. The findings from this study and from previous studies based on cross-sectional data[3,33-35] indicate that the label of "PCSs" after returning from deployment (which might be months after injury events) reflects a nonspecific set of symptoms that have more than 1 potential etiology, with concussion/MTBI being only 1 possible determinant. Therefore, treatments based on rehabilitation models for TBI are not likely to be effective. Further consideration should be given to applying collaborative care strategies based in primary care that are derived from the evidence-based literature on treatment of medically unexplained physical symptoms, somatoform disorders, and other ill-defined chronic symptom-based conditions.[61-63] Finally, this study clearly shows that PTSD is a serious postdeployment mental health problem for a subset of returning OIF veterans. Another recent study of OIF veterans supports this finding because PTSD was associated with more impairment in functioning and quality of life than any other postdeployment mental health disorder.[64] These data showing that PTSD often underlies persisting PCSs suggest that early identification and evidence-based treatment of PTSD may be critical to management of postdeployment PCSs. The VA's collaborative care model integrating mental health and primary care services may be a promising approach to reach veterans with PTSD.

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