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Original Contribution

Understanding Sequelae of Injury Mechanisms and Mild Traumatic Brain Injury Incurred during the Conflicts in Iraq and Afghanistan: Persistent Postconcussive Symptoms and Posttraumatic Stress Disorder

Aaron I. Schneiderman[1], Elisa R. Braver[1,2], and Han K. Kang[1,3]

[1] War-Related Illness and Injury Study Center, Washington DC VA Medical Center, Washington, DC.
[2] National Study Center for Trauma and Emergency Medical Systems, University of Maryland School of Medicine, Baltimore, MD.
[3] School of Public Health and Health Services, George Washington University, Washington, DC.

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A cross-sectional study of military personnel following deployment to conflicts in Iraq or Afghanistan ascertained histories of combat theater injury mechanisms and mild traumatic brain injury (TBI) and current prevalence of posttraumatic stress disorder (PTSD) and postconcussive symptoms. Associations among injuries, PTSD, and postconcussive symptoms were explored. In February 2005, a postal survey was sent to Iraq/Afghanistan veterans who had left combat theaters by September 2004 and lived in Maryland; Washington, DC; northern Virginia; and eastern West Virginia. Immediate neurologic symptoms postinjury were used to identify mild TBI. Adjusted prevalence ratios and 95% confidence intervals were computed by using Poisson regression. About 12% of 2,235 respondents reported a history consistent with mild TBI, and 11% screened positive for PTSD. Mild TBI history was common among veterans injured by bullets/shrapnel, blasts, motor vehicle crashes, air/water transport, and falls. Factors associated with PTSD included reporting multiple injury mechanisms (prevalence ratio = 3.71 for three or more mechanisms, 95% confidence interval: 2.23, 6.19) and combat mild TBI (prevalence ratio = 2.37, 95% confidence interval: 1.72, 3.28). The strongest factor associated with postconcussive symptoms was PTSD, even after overlapping symptoms were removed from the PTSD score (prevalence ratio = 3.79, 95% confidence interval: 2.57, 5.59).

Afghanistan; brain injuries; Iraq; post-concussion syndrome; stress disorders, post-traumatic; veterans; war; wounds and injuries

Abbreviations: OEF, Operation Enduring Freedom; OIF, Operation Iraqi Freedom; PCL-17, 17-item PTSD checklist; PCS 3+, three or more persistent postconcussive symptoms; PTSD, posttraumatic stress disorder; TBI, traumatic brain injury.

Nearly 1.6 million people were deployed to the wars in Iraq and Afghanistan—Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF), respectively—through June 30, 2007 (1). Medical air evacuations of 15,622 OIF and 2,386 OEF personnel occurred by August 4, 2007 (2, 3). Most injuries of OIF/OEF personnel do not require medical evacuation.

Blasts, vehicle crashes, and other mechanisms place OIF/OEF veterans at risk for traumatic brain injury (TBI) (4, 5). The Defense and Veterans Brain Injury Center reported that 16 percent of 596 soldiers had an alteration or loss of consciousness during deployment (6). Mild TBI may not be recognized at the time of injury. Most civilians with mild TBI recover completely within 3–6 months, but some develop persistent neuropsychiatric symptoms, often labeled postconcussive syndrome (7).

Combat service may result in posttraumatic stress disorder (PTSD) (8), and combat injuries increase PTSD risk (9).

Correspondence to Dr. Aaron I. Schneiderman, War-Related Illness and Injury Study Center, Washington DC VA Medical Center, 50 Irving Street NW (127), Washington, DC 20422 (e-mail: aaron.schneiderman@va.gov).

The estimated prevalence of PTSD among Active-duty soldiers following return from OIF ranges from 13 percent to 17 percent (9, 10) compared with 5 percent prior to deployment (10). Injured Active-duty OIF personnel had a higher PTSD prevalence than uninjured personnel did: 32 percent versus 14 percent (9). PTSD is associated with long-term health effects, including cardiovascular disease (11–13).

Overlapping symptoms hamper understanding of the relation between PTSD and postconcussive symptoms (9, 11, 14). PTSD and preexisting psychiatric disorders may increase the likelihood of postconcussive symptoms (14–16). The relation between mild TBI and PTSD has been debated (17–20), but a new study indicates a stronger association between mild TBI and PTSD than between other types of injury and PTSD (14). Based on a 2006 cross-sectional survey of 2,525 Army personnel in two combat infantry brigades about 3–4 months after their return from Iraq, Hoge et al. (14) observed that the highest prevalence of PTSD occurred among those soldiers who had lost consciousness. Loss of consciousness also was strongly associated with major depression. Mild TBI, whether or not loss of consciousness occurred, was significantly associated with postconcussive and other medical symptoms. After controlling for the presence of PTSD and depression, Hoge et al. did not observe an increased risk of postconcussive or other symptoms for Army personnel with a history of loss of consciousness, with the exception of headaches (14). Similarly, controlling for PTSD among solders with a mild TBI history who reported no loss of consciousness eliminated associations with postconcussive and other symptoms.

The purpose of this study was to estimate mild TBI occurrence in relation to combat theater injury mechanisms, estimate prevalence of PTSD and postconcussive symptoms, and examine associations of injury characteristics with PTSD and current postconcussive symptoms among military personnel deployed to OIF/OEF. This study complements that of Hoge et al. (14) by including all branches of the military and combat veterans of both Afghanistan and Iraq. Among personnel with histories of mild TBI, we were able to quantify associations between prevalence of postconcussive symptoms and other factors, including PTSD and injury characteristics.

MATERIALS AND METHODS

A self-administered mail questionnaire collected data on injury mechanisms, immediate postinjury symptoms suggesting mild TBI, PTSD, and postconcussive symptoms. Addresses were obtained from the National Change of Address databases and the US Department of Defense. The institutional review board of the Washington DC VA Medical Center approved the protocol.

Study population

The study population comprised 7,259 OIF/OEF veterans who had left combat theaters by September 30, 2004, and were living in northern Virginia; Maryland; Washington, DC; or eastern West Virginia. Active-duty personnel separated from the military and National Guard/Reserve members were included. Surveys were not delivered to 461 incorrect addresses. OIF/OEF veterans returned 2,235 surveys (34 percent participation rate).

Questionnaire

The anonymous survey, mailed during February 2005, included a letter explaining its purpose and how to gain access to Department of Veterans Affairs health care. A reminder postcard was sent 2 weeks later. The questionnaire (available at http://www.va.gov/WRIISC-DC/files/OIF_OEF_041405_postalsurvey.pdf) included the three-item Brief Traumatic Brain Injury Screen developed and clinically validated by the Defense and Veterans Brain Injury Center to detect mild TBI (6) and the 17-item PTSD checklist (PCL-17) (21). PCL-17 has strong correlations with other measures of PTSD and clinician-administered interviews (21–24) and includes PTSD criteria from the *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV* (25). PCL-17 scores range from 17 to 85, with higher values indicating more PTSD symptoms (21). Scores of 50 or higher were defined as indicative of PTSD (8, 23).

Veterans were asked about specific injury mechanisms. Severity of mild TBI was dichotomized on the basis of immediate symptoms following injury: level 1 (dazed/confused; having immediate concussion symptoms such as headaches, dizziness, or irritability) or level 2 (trouble remembering the injury, brief loss of consciousness, or self-reported head injury). The rationale for dichotomization was that amnesia regarding the injury event and loss of consciousness predict persistent symptoms and abnormal neuropsychological findings (18, 26, 27).

PCS 3+ was defined as self-attribution of three or more current neuropsychiatric symptoms to "a possible head injury or concussion," including headaches, dizziness, memory problems, balance problems, ringing in the ears, irritability, and sleep problems (28). Respondents had left combat theaters at least 5 months earlier; thus, reported symptoms were persistent.

Statistical methods

Stratified analyses explored the associations between variables of interest (injury mechanism, number of mechanisms, demographic characteristics, service in Iraq or Afghanistan) and outcomes (mild TBI, current postconcussive symptoms, PTSD). We also examined associations between outcomes (mild TBI and PTSD, PTSD and postconcussive symptoms). Chi-squared tests were used when comparing proportions. Crude prevalence ratios and 95 percent confidence intervals were calculated by using Cochran-Mantel-Haenszel methods for relative risks (29–31).

Poisson regression multivariate analyses of the associations between exposures and outcomes were conducted to generate adjusted prevalence ratios and their 95 percent confidence intervals (32, 33). We assigned the small number of veterans with missing values to the largest category (mode) within a variable, which served as the reference. Doing so resulted in conservative estimates of association. Models' goodness of fit was assessed by using log likelihoods, and models were checked for overdispersion.

TABLE 1. Prevalence of mild TBI,† PCS 3+,† and PTSD,† by conflict and gender, according to a postal survey of Iraq/Afghanistan veterans living in Maryland; northern Virginia; Washington, DC; and eastern West Virginia, 2005

Condition	Iraq only				Afghanistan only				Both conflicts			
	Male		Female		Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Mild TBI‡	146	13	21	11	35	11	4	8	61	12	8	12
PCS 3+§	50	5	8	4	10	3	2	4	25	5	2	3
PTSD¶	123	11	33	18*	18	6	5	10*	56	11	15	22*
Total	1,120	100	183	100	308	100	48	100	508	100	68	100

* $p < 0.01$ (chi-squared tests comparing female with male veterans in the same category).

† TBI, traumatic brain injury; PCS 3+, ≥3 persistent postconcussive symptoms; PTSD, posttraumatic stress disorder.

‡ Includes loss of consciousness, altered mental state (dazed/confused), not remembering injury, other concussive symptoms (headaches, irritability, dizziness), and reported head injury.

§ Includes headaches, dizziness, memory problems, balance problems, ringing in the ears, irritability, and sleep problems.

¶ PTSD scores ≥50 on a 17-item checklist.

Our PTSD and postconcussive symptoms measures had two overlapping symptoms: sleep problems and irritability. To address overlap, estimates of the association between PTSD and postconcussive symptoms were recomputed after omitting sleep problems and irritability from the PTSD score and lowering the PTSD threshold to 45 to mitigate the resulting reduction in sensitivity. Statistical analyses were performed with SAS 9.1 software (34).

RESULTS

Distributions by service category (Active-duty, National Guard, Reserve) and gender (86 percent male) were similar among 2,235 respondents versus the study population. Significantly more respondents were aged 41–65 years and fewer were aged 18–25 years (two-sided $p < 0.001$). Multivariate models controlled for age, lessening effects of differential response rates.

The 576 veterans deployed to both conflicts and 1,303 who served in only OIF had similar prevalences of mild TBI, PCS 3+, and PTSD (table 1). The 356 veterans who deployed to only Afghanistan had a slightly lower prevalence of PTSD. Compared with males, female veterans had a significantly higher PTSD prevalence.

Sports/physical training was the most commonly reported injury mechanism, followed by falls, blasts, and motor vehicle crashes (table 2). About 12 percent reported immediate symptoms following injury that were compatible with having received in-theater mild TBI.

Compared with veterans reporting sports/physical training as their sole injury mechanism, those injured by high-energy mechanisms such as falls were more likely to be categorized with mild TBI (table 2). Mild TBI increased with increasing numbers of reported injury mechanisms.

Factors associated with PTSD

About 11 percent of respondents were classified as having PTSD ($n = 250$). No adjustment for overdispersion was necessary. PTSD scores of 50 or higher (hereafter referred to as PTSD) were significantly more prevalent among the following groups: females, OIF veterans (vs. OEF-only veterans), those who reported multiple injury mechanisms, and those classified with level 1 or level 2 mild TBI (table 3). A nonsignificant increased prevalence of PTSD was observed among persons aged 18–30 years and those reporting high-energy injury mechanisms. Distinguishing blasts from other high-energy mechanisms did not improve model fit or suggest differences in the relation between blast exposures and PTSD. No significant differences were noted in PTSD by service category.

Factors associated with postconcussive symptoms

Of the 275 veterans categorized with in-theater mild TBI, 35 percent reported persistent PCS 3+. Poisson models were not overdispersed. PCS 3+ was significantly associated with reporting three or more injury mechanisms and level 2 mild TBI (table 4). The youngest veterans (aged 18–25 years) reported significantly less PCS 3+. No differences were noted by sex, service component, conflict, or exposure to high-energy injury mechanisms. Veterans exposed to blasts had a nonsignificant increase in PCS 3+ (prevalence ratio = 1.19, data not shown); distinguishing blasts from other high-energy mechanisms did not improve the model's fit.

PTSD was associated with a marked increase in prevalence of PCS 3+ (adjusted prevalence ratio = 3.85, 95 percent confidence interval: 2.59, 5.72) (table 4). After we excluded sleep problems and irritability/angry outbursts from PTSD scores and lowered the threshold to 45, the association between PTSD and PCS 3+ remained strong (adjusted prevalence ratio = 3.79). When we used the continuous revised PTSD scores, a prevalence ratio of 1.44 for PCS 3+ (95 percent confidence interval: 1.29, 1.60) was observed for each 10-point increase in the PTSD score (data not shown). An interaction term between level 2 mild TBI and PTSD was not significant.

TABLE 2. Prevalence ratios and 95% confidence intervals for mild TBI,* by external mechanism of injury and number of mechanisms, according to a postal survey of Iraq/Afghanistan veterans living in Maryland; northern Virginia; Washington, DC; and eastern West Virginia, 2005

External mechanism	No. of injured veterans	Mild TBI category†		No. of veterans with no mild TBI	Any mild TBI	
		Level 1	Level 2			
		No. of veterans	No. of veterans		PR*	95% CI*
Sports/physical training	338	50	28	260	2.84	1.71, 4.72
Sole reported injury‡	197	13	3	181	1.00	
Falls	257	54	52	151	5.08	3.11, 8.30
Sole reported injury	115	16	16	83	3.43	1.97, 5.96
Blasts	103	35	35	33	8.37	5.14, 13.63
Sole reported injury	32	10	7	15	6.54	3.69, 11.58
Motor vehicle crashes	76	32	23	21	8.91	5.46, 14.54
Sole reported injury	28	13	5	10	7.92	4.59, 13.65
Air/water transport	38	10	8	20	5.83	3.28, 10.39
Bullets/shrapnel	36	4	20	12	8.21	4.86, 13.85
Any injury mechanism reported	990	163	112	715		
1 mechanism§	732	96	52	584	1.00	
2 mechanisms	197	46	37	114	2.08	1.68, 2.59
≥3 mechanisms	61	21	23	17	3.57	2.89, 4.41

* TBI, traumatic brain injury; PR, prevalence ratio; CI, confidence interval.
† Level 2 mild TBI: loss of consciousness, amnesia, or self-reported head injury; level 1 mild TBI: other immediate mild TBI symptoms.
‡ Reference group for prevalence ratios by external mechanism.
§ Reference group for prevalence ratios by number of injury mechanisms.

The following percentages of veterans reported physician diagnoses of head injury: 30 percent with PCS 3+, 27 percent with level 2 mild TBI, 9 percent with level 1 mild TBI, and 4 percent of those classified as no TBI. Among veterans screening positive for PTSD, 44 percent said a physician had told them they had PTSD; 5 percent of other veterans said they had been diagnosed with PTSD.

DISCUSSION

Injuries during deployment were common among respondents, with 44 percent reporting at least one mechanism. Mild TBI arose from well-recognized combat hazards and other mechanisms including motor vehicle crashes and falls. Factors significantly associated with positive PTSD screens included OIF service, female gender, multiple injury mechanisms, and mild TBI. Persistent symptoms following mild TBI were significantly associated with level 2 (more-severe) mild TBI, multiple injury mechanisms, and PTSD. Multiple injury mechanisms may be a marker for high exposure to combat hazards and perhaps repeat, mild TBI events.

PTSD prevalence among respondents was similar to that in other studies of OIF/OEF veterans (9, 10); lower incidence (9 percent) of PTSD among combat veterans has been reported (35). The higher PTSD prevalence among female veterans was consistent with previous research (36). Other researchers used PCL-17 scores lower than 50 to increase sensitivity (22, 24) among women; however, our PTSD threshold of 50 was reasonable for our mostly male study population. As suggested by Hoge et al. (14), mild TBI's strong association with PTSD may be due to life-threatening combat experiences that can result in mild TBI or PTSD. Another possibility is that, in some cases, symptoms associated with PTSD may be a manifestation of brain injury. Hoge et al.'s (14) findings of strong associations with PTSD and depression among soldiers who had lost consciousness could reflect neurologic insult as well as traumatic stress.

PTSD was the strongest factor associated with reporting PCS 3+, even after we excluded symptoms that overlap with postconcussive symptoms. Women did not have an increased prevalence of PCS 3+ after we adjusted for other factors. An association between PTSD and somatic complaints is consistent with past research (9, 11, 14). As posited by Hoge et al. (14), PTSD might be an effect modifier following mild TBI. If PTSD indicates neurologic insult, this also could explain its association with PCS 3+. Unlike Hoge et al. (14), this study did not assess the presence of depression, which could have affected the relation between PTSD and PCS 3+. Future studies of the effects of mild TBI should measure depression in addition to PTSD and address the overlapping symptoms between PTSD and depression.

TABLE 3. Crude and adjusted prevalence ratios and 95% confidence intervals for PTSD,* by injury mechanisms, mild TBI,* demographic characteristics, and military characteristics, according to a postal survey of Iraq/Afghanistan veterans living in Maryland; northern Virginia; Washington, DC; and eastern West Virginia, 2005

Exposure variable	Total no.	No. with PTSD	Crude PR*	Adjusted PR†	95% CI*
Age group (years)					
18–25	380	58	1.58	1.20	0.89, 1.62
26–30	329	46	1.45	1.28	0.93, 1.77
31–35	339	33	1.01	0.89	0.63, 1.26
36–40	368	32	0.90	0.90	0.62, 1.30
≥41	808	78	1.0	1.00	
Gender					
Female	299	53	1.73	1.81	1.37, 2.38
Male	1,918	196	1.0	1.00	
Service component					
National Guard	646	66	0.92	1.11	0.84, 1.46
Active-duty	614	75	1.10	1.15	0.89, 1.48
Reserve	930	103	1.0	1.00	
Conflict					
Iraq only or both	1,879	227	1.87	1.66	1.12, 2.45
Afghanistan only	356	23	1.0	1.00	
No. of injury mechanisms					
0	1,245	58	1.0	1.00	
1	732	104	3.05	2.04	1.45, 2.88
2	197	57	6.21	2.86	1.83, 4.45
≥3	61	31	10.91	3.71	2.23, 6.19
High-energy injury mechanism(s)‡					
Yes	407	122	4.28	1.32	0.95, 1.83
No	1,828	128	1.0	1.00	
Mild TBI level§					
Level 1	163	56	4.78	2.37	1.72, 3.28
Level 2	112	53	6.58	3.00	2.15, 4.18
None	1,960	141	1.0	1.00	

* PTSD, posttraumatic stress disorder; TBI, traumatic brain injury; PR, prevalence ratio; CI, confidence interval.

† Adjusted for age group, gender, service component, conflict, number of injury mechanisms, high-energy injury mechanisms, and mild TBI level.

‡ Includes blasts, bullets/shrapnel, motor vehicle crashes, falls, and air/water transport; excludes sports and other mechanisms.

§ Level 2: loss of consciousness, amnesia, or self-reported head injury; level 1: other immediate mild TBI symptoms.

Respondents may not have been fully representative of OIF/OEF veterans. Active-duty personnel who remained in the military could not be surveyed by the Department of Veterans Affairs. Respondents resembled the total population surveyed by gender and service category, but they were older. Symptomatic veterans may have been more likely to

TABLE 4. For veterans with mild TBI,* crude and adjusted prevalence ratios and 95% confidence intervals for PCS 3+,* by injury mechanisms, mild TBI levels, demographic characteristics, and military characteristics, according to a postal survey of Iraq/Afghanistan veterans living in Maryland; northern Virginia; Washington, DC; and eastern West Virginia, 2005

Exposure variable	Total no.	No. with PCS 3+	Crude PR*	Adjusted PR†	95% CI*
Age group (years)					
18–25	62	16	0.55	0.62	0.38, 0.99
26–30	43	17	0.85	0.91	0.60, 1.36
31–35	45	12	0.57	0.63	0.39, 1.03
36–40	35	10	0.61	0.78	0.48, 1.27
≥41	88	41	1.0	1.00	
Gender					
Female	33	12	1.04	1.03	0.69, 1.54
Male	241	84	1.0	1.00	
Service component					
National Guard	82	35	1.45	1.00	0.72, 1.38
Active-duty	71	22	1.05	0.90	0.62, 1.32
Reserve	112	33	1.0	1.00	
Conflict					
Iraq only or both	236	85	1.17	1.05	0.69, 1.61
Afghanistan only	39	12	1.0	1.00	
No. of injury mechanisms					
1	148	39	1.0	1.00	
2	83	34	1.55	1.31	0.94, 1.83
≥3	44	24	2.07	1.50	1.02, 2.22
High-energy injury mechanism(s)‡					
Yes	193	76	1.54	1.02	0.69, 1.52
No	82	21	1.0	1.00	
Mild TBI level§					
Level 1	163	44	1.0	1.00	
Level 2	112	53	1.75	1.42	1.06, 1.92
PTSD* threshold ≥50					
Yes	109	72	4.39	3.85	2.59, 5.72
No	166	25	1.0	1.00	
PTSD threshold ≥45 excluding sleep/irritability	102			3.79	2.57, 5.59

* TBI, traumatic brain injury; PCS 3+, ≥3 persistent postconcussive symptoms; PR, prevalence ratio; CI, confidence interval; PTSD, posttraumatic stress disorder.

† Adjusted for age group, gender, service component, conflict, number of injury mechanisms, high-energy injury mechanisms, mild TBI level, and PTSD.

‡ Includes blasts, bullets, shrapnel, motor vehicle crashes, falls, and air/water transport; excludes sports and other mechanisms.

§ Level 2: loss of consciousness, amnesia, or self-reported head injury; level 1: other immediate mild TBI symptoms.

respond; however, neither their PTSD prevalence nor their mild TBI history were higher than that reported by surveys of Active-duty personnel (6, 9, 10).

Veterans attributing persistent symptoms to a head injury may have better recall of postinjury symptoms indicative of mild TBI, which could explain the relatively high percentage (35 percent) of veterans classified with mild TBI who reported PCS 3+. This is a limitation of the cross-sectional design. Prospective follow-up of those with mild TBI symptoms in the combat theater would improve estimates of the risk of developing chronic symptoms and understanding of causal pathways for persistent symptoms. Nonetheless, classifying mild TBI based on immediate postinjury symptoms made it possible to distinguish the occurrence of mild TBI from postconcussive symptoms. In clinical settings, mild TBI diagnoses commonly incorporate persistent postconcussive symptoms.

Other studies enrolled only Active-duty personnel or those seeking care, who are not necessarily representative of all combat veterans, whereas this study included National Guard and Reserve members and was not confined to patients (37). This survey provided estimates of PTSD prevalence and PCS 3+ that might not have been evident when these veterans completed routine postdeployment health assessments. Anonymity of survey responses reduced potential concerns about adverse effects on careers. PTSD is underestimated when prevalence is based on diagnoses made in Department of Defense medical facilities (35, 38). Injuries incurred during deployment may not result in an official report, but they might result in persistent symptoms. This population-based survey could capture such injuries.

These findings suggest that a substantial number of OIF/OEF veterans are experiencing physical and psychological health complaints associated with deployment injuries. This study likely underestimates the injury burden among OIF/OEF veterans because attacks on troops have escalated since September 2004 (39). It would have been desirable to analyze the effects of duration and intensity of combat in relation to adverse health outcomes; Hoge et al. (14) observed a higher PTSD prevalence among soldiers with higher combat intensity scores.

The Department of Defense and the Department of Veterans Affairs have instituted routine screening for TBI, postconcussive symptoms, PTSD, and psychiatric symptoms among OIF/OEF veterans (40–42). A substantial proportion of veterans with PCS 3+ or positive PTSD screens reported no physician diagnoses for these conditions; this finding suggests that many veterans have not sought treatment for symptoms related to deployment. Our findings and those of Hoge et al. (14) point to the importance of clinical assessment of PTSD and depression when determining appropriate treatment methods for veterans experiencing postconcussive symptoms. When we examined PTSD as a continuous variable, we observed an increased risk of PCS 3+ for each 10-point increase in PTSD screening score, which suggests that clinicians should consider PTSD a condition with a spectrum from mild to severe rather than as a diagnosis that is either present or absent. Continued monitoring and intervention among OIF/OEF veterans are needed.

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