Examining the Relation Between Combat-Related Concussion, a Novel 5-Factor Model of Posttraumatic Stress Symptoms, and Health-Related Quality of Life in Iraq and Afghanistan Veterans

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ABSTRACT

Objective: This study examined demographic, military, and clinical characteristics associated with combat-related concussion and persistent postconcussive symptoms; and how combat-related concussion and persistent postconcussive symptoms and a novel 5-factor model of posttraumatic stress disorder (PTSD) symptoms are related to physical and mental health–related quality of life in veterans who served in Iraq and Afghanistan.

Method: 233 veterans recruited from the Veterans Affairs Hawaii Program Registry who served in Iraq and Afghanistan completed a survey in 2010 that assessed combat-related concussion and persistent postconcussive symptoms, PTSD (*DSM-IV* criteria), alcohol use problems, and physical and mental health–related quality of life. The primary measure was physical and mental health–related quality of life as assessed by the 12-item Short-Form Health Survey, version 2.

Results: Veterans who screened positive for combat-related concussion and persistent postconcussive symptoms were more likely than those who did not to report direct combat exposure ($\chi^2 = 15.46$, P < .001), living in a rural area ($\chi^2 = 6.86$, P < .01), and screening positive for PTSD (χ^2 = 37.67, P < .001) and alcohol use problems ($\chi^2 = 11.62$, P < .01); 57.3% of veterans who screened positive for combat-related concussion and persistent postconcussive symptoms screened positive for PTSD. In bivariate analyses, combat-related concussion and persistent postconcussive symptoms were associated with lower scores on measures of physical and mental health-related quality of life (r = -0.27 to -0.45, P < .001). In multivariate analyses, combatrelated concussion and persistent postconcussive symptoms were no longer related to these outcomes, with PTSD-related dysphoric arousal symptoms as the strongest predictor of physical health-related quality of life ($\beta = -0.55$, P < .001) and PTSD-related emotional numbing symptoms ($\beta = -0.56$, P < .001) as the strongest predictor of mental health-related quality of life.

Conclusions: Results of this study suggest that a 5-factor model of PTSD symptoms may provide greater specificity in understanding the relation between combat-related concussion and persistent postconcussive symptoms, PTSD symptoms, and health-related physical and mental quality of life in Iraq/ Afghanistan veterans. Psychiatric clinicians should consider this heterogeneity of PTSD symptoms when assessing and treating symptomatic veterans.

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merican military forces serving in Operations Enduring A Freedom, Iraqi Freedom, and New Dawn experience high rates of exposure to potential physical trauma and injuries.^{1,2} Particular concern has been raised about the possible longterm effects of concussion and mild traumatic brain injury that may result from proximity to blast explosions.³⁻⁵ Concussion/ mild traumatic brain injury, which is characterized by brief loss or alteration of consciousness, is a relatively common injury experienced by veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn.⁶ According to a nationally representative survey of veterans of Operations Enduring Freedom and Iraqi Freedom, 19.5% or an estimated 320,000 veterans had sustained a concussion/mild traumatic brain injury during deployment, with the majority being untreated for this condition.¹ Although many individuals recover fully within 6 months of a concussion/mild traumatic brain injury, some continue to experience a range of persistent postconcussive symptoms, such as headaches, sensitivity to light, impaired cognition, and irritability.7-9

Concussion/mild traumatic brain injury is known to cooccur with mental health problems,^{10–13} and only recently has the comorbidity of posttraumatic stress disorder (PTSD) and concussion/mild traumatic brain injury received widespread attention due to the relatively high prevalence of these conditions among veterans of Operations Enduring Freedom and Iraqi Freedom.^{14–17} Among veterans of Operations Enduring Freedom and Iraqi Freedom, a population-based study of US Army personnel conducted 3-4 months after their return from a 1-year deployment found that 44% of those who reported a loss of consciousness and 27% of those who reported altered mental status during their service met criteria for PTSD compared to 9% who did not report an injury.¹⁸ Another study of veterans of Operations Enduring Freedom and Iraqi Freedom found that 12% screened positive for history of concussion/ mild traumatic brain injury, which was associated with a more than 2-fold greater likelihood of PTSD.¹⁹

Recent research has begun to explore whether combatrelated concussion/mild traumatic brain injury and PTSD might have similar or interactive pathways to long-term functional difficulties. A widely known study of US Army infantry soldiers¹⁸ found that while concussion/mild traumatic brain injury was associated with poor general health, missed worked days, medical visits, and a higher number of somatic and postconcussive symptoms, these associations were no longer significant after adjustment for PTSD and depression. Similarly, a study in Connecticut of veterans of Operations Enduring Freedom and Iraqi Freedom found that concussion/ mild traumatic brain injury was associated with fair/poor

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overall health, unmet medical and psychological needs, and psychosocial difficulties, but that these associations were no longer significant after adjustment for PTSD.¹³ More recently, a longitudinal study of Operation Iraqi Freedom National Guard soldiers found that PTSD symptoms assessed in Iraq 1 month prior to returning home were a stronger predictor of a range of psychosocial and functional outcomes 1 year later than concussion/mild traumatic brain injury.²⁰

While PTSD symptoms may help explain the relation between combat-related concussion/mild traumatic brain injury and functional difficulties in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn, PTSD is a heterogeneous disorder that is characterized by distinct symptom clusters found to be independently associated with functioning.²¹⁻²³ A novel 5-factor model of PTSD symptomatology comprised separate clusters of reexperiencing, avoidance, emotional numbing, dysphoric arousal, and anxious-arousal symptoms²⁴ has been found to be the best-fitting model of PTSD symptoms in several confirmatory factor analytic studies of veteran^{25,26} and civilian samples.²⁴⁻²⁹ To date, no study has examined how PTSD symptom clusters that comprise the 5-factor model may be differentially related to health-related quality-of-life outcomes after adjustment for concussion/mild traumatic brain injury and demographic and other clinical characteristics in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn.

Given prior research suggesting that PTSD symptoms characterized by sleep difficulties and irritability may be linked to poorer physical functioning,^{30–33} and that emotional numbing symptoms may independently account for chronic difficulties in mental functioning,^{34–36} symptom clusters of this novel 5-factor model of PTSD may be differentially related to physical and mental health–related quality of life. Characterization of PTSD symptom clusters associated with specific aspects of functioning may help inform the development of targeted interventions to address functional difficulties in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn.

The current study had 2 aims. First, we examined demographic, military, and clinical characteristics associated with combat-related concussion/mild traumatic brain injury in a diverse cohort of veterans in Operations Enduring Freedom, Iraqi Freedom, and New Dawn from Hawaii. Second, we examined how specific symptom clusters of a novel 5-factor model of PTSD are related to health-related quality of life after adjustment for concussion/mild traumatic brain injury and other demographic and clinical covariates. On the basis of prior research,³⁰⁻³⁶ we hypothesized that (1) a positive screen for concussion/mild traumatic brain injury would be associated with poorer health-related quality of life and (2), after adjustment for concussion/mild traumatic brain injury and other demographic and clinical covariates, dysphoric arousal symptoms would be most strongly associated with physical health-related quality of life, whereas emotional numbing symptoms would be most strongly associated with mental health-related quality of life.

- Veterans who screen positive for a combat-related concussion and persistent postconcussive symptoms should be screened for posttraumatic stress disorder.
- Posttraumatic stress disorder treatments that target dysphoric arousal and emotional numbing symptoms may help improve physical and mental health—related quality of life, respectively.
- Clinicians should assess, treat, and monitor the psychological sequelae of combat-related concussion among veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn.

METHOD

Study Sample

Participants were a stratified sample of 233 veterans from a Veterans Affairs (VA) Hawaii Program Registry for Operations Enduring Freedom, Iraqi Freedom, and New Dawn. Stratified sampling methods were employed to ensure an equal number of rural versus urban veterans and a proportion of female veterans equivalent to that of the overall veteran population from Operations Enduring Freedom, Iraqi Freedom, and New Dawn. All participants provided informed consent to participate in the study, and data were collected from November to December of 2010. Of 450 veterans who were mailed surveys, 233 (52%) responded and were included in this study. Compared to the 2,542 veterans registered with the VA Hawaii Program Registry for Operations Enduring Freedom, Iraqi Freedom, and New Dawn, the study sample was not significantly different in terms of age, gender, or marital status. Compared to national samples of veterans of Operations Enduring Freedom and Iraqi Freedom,^{1,37} the study sample was older, more likely to be married, and more likely to be Asian American/Pacific Islander.

Measures

Combat-related concussion and persistent postconcussive symptoms. A 4-item screen created by the VA from a tool developed by the Defense and Veterans Brain Injury Center was used to screen for history of combat-related concussion and persistent postconcussive symptoms.^{38,39} The first item asked, "During your [Operation Enduring Freedom/ Operation Iraqi Freedom] deployment(s), did you experience any of the following events?" with response options being "blast or explosion," "vehicular accident/crash (including aircraft)," "fragment wound or bullet wound above the shoulders," "fall," and "none of the above." Only participants who reported that they experienced 1 or more of the above events were asked to respond to the other 3 items. The second item asked, "Did you have any of these symptoms immediately afterwards" with response options being "losing consciousness/knocked out," "being dazed, confused, or seeing stars," "not remembering the event," "concussion," and "head injury." The third item asked, "Did any of the following problems

begin or get worse afterwards?" with response options being "memory problems or lapses," "balance problems or dizziness," "sensitivity to bright light," "irritability/easily annoyed," "headaches," and "sleep problems." The fourth item asked, "In the past 4 weeks, have you had any of these problems?" with response options being "memory problems or lapses," "balance problems or dizziness," "sensitivity to bright light," "irritability," "headaches," and "sleep problems."

We computed the proportion of participants who reported that they experienced a combat-related concussion (ie, positive endorsement of only the first 2 questions of the screening instrument), as well as those who reported a combat-related concussion with persistent postconcussive symptoms (ie, positive endorsement of all 4 questions of the screening instrument).

A total of 79 veterans (33.9%) screened positive for a combat-related concussion, and 75 (32.2%) screened positive for combat-related concussion and persistent postconcussive symptoms. Thus, the vast majority (94.9%) of veterans who screened positive for a concussion also screened positive for persistent postconcussive symptoms, with only 4 respondents (5.1%) screening positive for a concussion but not persistent postconcussive symptoms. As a result, we conservatively operationalized combat-related concussion to include persistent postconcussive symptoms and focused our analyses on veterans who reported combat-related concussion and persistent postconcussive symptoms.

PTSD. The PTSD Checklist-Civilian Version (PCL-C)⁴⁰ is a self-report assessment of PTSD symptoms developed by the National Center for PTSD, which contains 17 items directly adapted from the diagnostic criteria for PTSD in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV).⁴¹ Participants are asked to report the severity of a variety of PTSD symptoms from 1 (not at all) to 5 (extremely), with a total score \geq 50 and endorsement of moderate or greater severity of symptoms within each of the symptom clusters for a DSM-IV diagnosis of PTSD indicative of a positive screen for PTSD. The PCL-C has demonstrated good internal consistency and testretest reliability.42,43 While the PCL-C does not specifically assess PTSD symptoms related to military experience, a recent study found that using the PCL-C in military survey research did not affect PTSD symptom reporting or prevalence estimates.44

Posttraumatic stress disorder symptom clusters were modeled according to a novel 5-factor model of PTSD symptoms.^{24,26,28} This 5-factor model is composed of intercorrelated factors that reflect symptoms of reexperiencing (5 items), avoidance (2 items), emotional numbing (5 items), dysphoric arousal (3 items), and anxious arousal (2 items). *DSM-IV* PTSD symptoms B1–B5 load on a reexperiencing factor; symptoms C1 and C2 load on an avoidance factor; symptoms C3–C7 load on an emotional numbing factor; symptoms D1–D3 load on a dysphoric arousal factor. In the current sample of veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn, this model of PTSD symptom structure provided a significantly better representation of PTSD symptom dimensionality than the *DSM-IV* and 4-factor dysphoria and emotional numbing models.²⁶

Health-related quality of life. The 12-item Short-Form Health Survey, version 2 $(SF-12v2)^{45}$ is a widely used measure of physical and mental health functioning. Eight standardized subscales and total physical component summary and mental component summary scores are generated. The 8 subscales are physical functioning, role-physical, bodily pain, general health, vitality, social functioning, roleemotional, and mental health. All subscale and component scores range from 0 to 100, with a score of 50 representing the average level of functioning in the general population and each 10-point interval representing 1 standard deviation. Higher scores indicate better health.

Alcohol use problems. The CAGE screen⁴⁶ was used to identify probable alcohol use problems. The questions on the screen focus on Cutting down, Annoyance by criticism, Guilty feeling, and Eye openers. Despite its brevity, the CAGE is a reliable screener for alcohol use problems and has shown high test-retest reliability in veteran populations.⁴⁷

Data Analysis

First, independent *t* tests and χ^2 tests were computed to compare veterans who did and those who did not screen positive for combat-related concussion and persistent postconcussive symptoms on demographic, military, and clinical characteristics, and health-related quality-of-life variables. Six participants had minimal item-level data missing (1–3 items each) on the PCL-C. Maximum likelihood procedures were employed to estimate these values.⁴⁸

Pearson correlations were then conducted to examine the association between health-related quality of life and demographics, military, and clinical characteristics; between health-related quality of life and a positive screen for concussion with and without persistent postconcussive symptoms; between health-related quality of life and the 5-factor model of PTSD symptoms; and between a positive combatrelated concussion and persistent postconcussive symptoms screen and the PCL total score and 5-factor model of PTSD symptoms.

Second, 2 multivariate analyses of covariance (MANCOVAs) were conducted to examine how combatrelated concussion and persistent postconcussive symptoms and PTSD screening status relates to health-related quality of life. Participants were grouped into 1 of 4 categories: no combat-related concussion and persistent postconcussive symptoms or PTSD, combat-related concussion and persistent postconcussive symptoms only, PTSD only, and comorbid combat-related concussion and persistent postconcussive symptoms and PTSD. Demographic variables that differed between groups were entered as covariates, and SF-12v2 physical component summary and mental component summary scores were entered as dependent variables in the first model; the 8 SF-12v2 subscales were entered as dependent variables in the second model. Post hoc analyses comparing these 4 groups were conducted using Tukey

	No Positive Screen for Concussion and	Positive Screen for Concussion and	
Variable	Persistent Postconcussive Symptoms (n = 158)	Postconcussive Symptoms (n=75)	Test of Difference
Age, mean (SD), y	37.2 (10.5)	35.9 (9.9)	$t_{226} = 0.90$
Male gender, n (%)	133 (84.7)	69 (92.0)	$\chi^2_1 = 2.39$
Married/in a long-term relationship, n (%)	112 (71.8)	52 (69.3)	$\chi^2_1 = 0.15$
Race, n (%)			$\chi^2_1 = 0.49$
Asian/Pacific Islander	85 (53.8)	44 (58.7)	
Other	73 (46.2)	31 (41.3)	
Education, n (%)			$\chi^2_2 = 2.95$
Some/completed high school	30 (19.1)	20 (26.7)	14 2
Some/completed college	102 (65.0)	48 (64.0)	
Some/completed graduate school	25 (15.92)	7 (0.3)	
Military branch, n (%)			$\chi^2_4 = 2.63$
Army	110 (69.6)	59 (78.7)	
Marines	18 (11.4)	7 (9.3)	
Navy	14 (8.9)	5 (6.7)	
Air Force/Coast Guard	16 (10.1)	4 (5.3)	
Combat exposure, n (%) ^a	66 (41.8)	52 (69.3)	$\chi^2_1 = 15.46^{***}$
Employed full-time, n (%)	89 (57.1)	34 (46.0)	$\chi^2_4 = 2.49$
Rural geography, n (%)	70 (44.3)	47 (62.7)	$\chi^2_1 = 6.86^{**}$
Service duty, n (%)			$\chi^2_1 = 0.24$
Active duty	78 (49.4)	34 (46.0)	
National Guard/reserves	80 (50.6)	40 (54.1)	
Positive PTSD screen, n (%) ^b	28 (17.7)	43 (57.3)	$\chi^2_1 = 37.67^{***}$
Positive CAGE screen, n (%) ^c	26 (16.9)	27 (37.5)	$\chi^2_1 = 11.62^{**}$

Table 1. Background Characteristics of Veterans With and	Without a Positive Screen for Concussion and Persistent
Postconcussive Symptoms (n = 233)	

^aCombat exposure is defined as serving in a direct combat or combat operations role.

bScore of 50 or greater on the PTSD Checklist-Civilian Version and endorsement of moderate or greater severity of at least 1 reexperiencing, 3 avoidance/ numbing, and 2 hyperarousal symptoms consistent with DSM-IV diagnosis of PTSD.

Score of 2 or greater on the CAGE, a measure for alcohol use. The questions in the screen focus on Cutting down, Annoyance by criticism, Guilty feeling, and Eye openers. **P<.01, ***P<.001.

Abbreviation: PTSD = posttraumatic stress disorder.

honestly significant difference test. We used SPSS statistical software, version 17.0,49 to conduct these analyses.

Third, structural equation models were conducted by using EQS 6.1⁵⁰ to examine associations between combatrelated concussion and persistent postconcussive symptoms, PTSD symptom clusters, alcohol use problems, and healthrelated quality of life. One set of models was conducted with SF-12v2 physical component summary scores as the dependent variable; and another with SF-12v2 mental component summary scores as the dependent variable. In both sets of models, we first examined the relation between combat-related concussion and persistent postconcussive symptoms screening status and SF-12v2 summary measures (SF-12v2 scores were entered into analyses as raw summary scores). We then added the 5-factor PTSD model consisting of reexperiencing, avoidance, emotional numbing, dysphoric arousal, and anxious arousal symptoms loading on separate factors. As described in greater detail elsewhere,²⁶ each of the PCL items was specified to load on a single latent factor, all factors were allowed to correlate, all error covariances were fixed to 0, and all tests were 2-tailed. Demographic and clinical variables associated with SF-12v2 physical component summary and mental component summary scores at the .05 level in bivariate analyses were also entered as covariates. If 1 or more PTSD factor scores were associated significantly with either of the SF-12v2 summary scores, post hoc analyses were conducted to examine specific symptoms associated with these scores; a was set to .001 in these analyses to reduce the likelihood of making a type

1 error. Post hoc analyses were also conducted to examine the relation between combat-related concussion and persistent postconcussive symptoms, PTSD symptom clusters, and SF-12v2 subscale scores; a was also set to .001 in these analyses.

RESULTS

Table 1 shows that, compared to veterans who did not screen positive for combat-related concussion and persistent postconcussive symptoms, those who did screen positive for combat-related concussion and persistent postconcussive symptoms were significantly more likely to have direct combat exposure, live in a rural area, and screen positive for PTSD and alcohol use problems.

Bivariate analyses indicated that older age, having direct combat exposure, and screening positive for PTSD were associated with lower SF-12v2 physical component summary scores. Lower levels of education, direct combat exposure, non-full-time employment, screening positive for PTSD, and alcohol use problems were associated with lower SF-12v2 mental component summary scores.

As shown in Table 2, bivariate analyses indicated that combat-related concussions with and without persistent postconcussive symptoms were both significantly associated with lower scores on all SF-12v2 scales (r values = -0.25to -0.45); the 5 factors of PTSD symptoms were also significantly correlated with lower scores on all SF-12v2 scales (r values = -0.26 to -0.80).

Table 2. Bivariate Correlations Between Combat-Related Concussion, 5-Factor Model of PTSD Symptoms, and SF-12v2 Scores

	SF-12v2 Physical	SF-12v2 Mental	SF-12v2 Subscale							
	Component	Component	Physical	Role-	Bodily	General		Social	Role-	Mental
	Summary	Summary	Functioning	Physical	Pain	Health	Vitality	Functioning	Emotional	Health
Concussion	-0.25***	-0.38***	-0.29***	-0.38***	-0.25***	-0.32***	-0.31***	-0.34***	-0.42***	-0.37***
Combat-related concussion and persistent postconcussive symptoms	-0.27***	-0.39***	-0.31***	-0.40***	-0.28***	-0.36***	-0.32***	-0.35***	-0.45***	-0.38***
PTSD: reexperiencing	-0.35***	-0.74^{***}	-0.42^{***}	-0.55***	-0.49***	-0.54***	-0.54***	-0.69***	-0.73***	-0.71***
PTSD: avoidance	-0.26***	-0.66***	-0.35***	-0.39***	-0.41***	-0.44***	-0.50***	-0.59***	-0.62***	-0.63***
PTSD: numbing	-0.39***	-0.80***	-0.48^{***}	-0.60***	-0.54***	-0.56***	-0.60***	-0.78***	-0.77^{***}	-0.76***
PTSD: dysphoric arousal	-0.47^{***}	-0.76***	-0.51***	-0.65***	-0.58***	-0.62***	-0.61***	-0.74^{***}	-0.76***	-0.74***
PTSD: anxious arousal	-0.30***	-0.65***	-0.37***	-0.52***	-0.40***	-0.44^{***}	-0.51***	-0.58^{***}	-0.66***	-0.62***
***P<.001.	umatic stress of	lisorder SE-12	$2v^2 = 12$ Item 9	Short-Form	Health Su	rvev versio	n ?			

Table 3. Multivariate Analysis of Variance of Health-Related Quality of Life Veterans by PTSD and Combat-Related Concussion and Persistent Postconcussive Symptoms Screening Status^a

	(1)	(2)		(4)		
	No PTSD or	Combat-Related		Combat-Related		
	Combat-Related	Concussion		Concussion		
	Concussion	and Persistent		and Persistent		
	and Persistent	Postconcussive	(3)	Postconcussive		
	Postconcussive	Symptoms	PTSD Only	Symptoms and		Post Hoc
Variable, Mean (SD)	Symptoms (n=120)	Only $(n=26)$	(n = 38)	PTSD $(n=49)$	$F_{3,192}$	Analyses ^b
Model 1						
SF-12v2 physical component summary score ^c	48.8 (1.0)	45.3 (2.4)	42.6 (1.7)	39.4 (1.8)	7.98***	1>3, 4
SF-12v2 mental component summary score	47.6 (1.0)	43.0 (2.5)	32.7 (1.8)	29.3 (1.9)	33.61***	1, 2>3, 4
Model 2						
Physical functioning subscale score	51.6 (1.0)	48.6 (2.4)	43.8 (1.7)	39.9 (1.8)	12.91***	1 > 3, 4; 2 > 4
Role-physical subscale score	49.0 (1.0)	42.4 (2.3)	39.2 (1.7)	36.2 (1.7)	18.85***	1>2, 3, 4; 2>4
Bodily pain subscale score	45.9 (1.1)	44.3 (2.7)	37.3 (2.0)	33.0 (2.1)	12.39***	1 > 3, 4; 2 > 4
General health subscale score	44.7 (1.0)	40.1 (2.4)	36.1 (1.7)	32.7 (1.8)	14.09***	1 > 3, 4; 2 > 4
Vitality subscale score	52.2 (1.0)	47.8 (2.3)	41.7 (1.6)	41.2 (1.7)	16.80***	1, 2>3, 4
Social functioning subscale score	45.9 (1.1)	42.8 (2.6)	32.8 (1.8)	28.4 (1.9)	27.44***	1, 2>3, 4
Role-emotional subscale score	47.3 (1.1)	41.1 (2.5)	31.7 (1.8)	26.0 (1.9)	40.73***	1 > 2 > 3 > 4
Mental health subscale score	48.2 (1.0)	44.6 (2.4)	35.5 (1.7)	32.8 (1.8)	26.16***	1, 2>3, 4

^aMultivariate analyses controlled for group differences on background characteristics.

^b1 = No PTSD or combat-related concussion and persistent postconcussive symptoms, 2 = combat-related concussion and persistent postconcussive symptoms only, 3 = PTSD only, 4 = combat-related concussion and persistent postconcussive symptoms and PTSD.

^cGreater scores on all SF-12 summary scores and subscales indicate greater health-related quality of life.

Abbreviations: PTSD = posttraumatic stress disorder, SF-12v2 = 12-Item Short-Form Health Survey, version 2.

A positive screen for combat-related concussion and persistent postconcussive symptoms was associated with total scores on the PCL (r=0.51, P<.001), as well as reexperiencing (r=0.46, P<.001), avoidance (r=0.37, P<.001), emotional numbing (r=0.44, P<.001), dysphoric arousal (r=0.49, P<.001), and anxious arousal (r=0.51, P<.001) symptoms. However, the magnitudes of these correlations did not meet or exceed 0.80, which often indicates possible multicollinearity,⁵¹ and collinearity diagnostics suggested that entering concussion and persistent postconcussive symptoms with PTSD symptom clusters as independent variables in analyses of SF-12v2 physical component summary and mental component summary scores did not introduce multicollinearity (tolerance values = 0.70 to 0.73; variance inflation factors = 1.37 to 1.42).

As shown in Table 3, in the first model, when we controlled for group differences on background characteristics, veterans who screened positive for combat-related concussion and persistent postconcussive symptoms and PTSD or who screened positive for PTSD only had lower SF-12v2

physical component summary scores than those who did not screen positive for combat-related concussion and persistent postconcussive symptoms or PTSD. Veterans who screened positive for combat-related concussion and persistent postconcussive symptoms and PTSD or screened positive for PTSD only also had lower SF-12v2 mental component summary scores than veterans who screened positive for combat-related concussion and persistent postconcussive symptoms only or those who did not screen positive for either condition. In the second model, MANCOVAs of the 8 subscales of the SF-12v2 revealed similar results, showing veterans who screened positive for combat-related concussion and persistent postconcussive symptoms and PTSD and those who screened positive for PTSD only reported lower scores on all 8 subscales than the 2 other groups who did not screen positive for PTSD.

Table 4 shows results of multivariate analyses of variables associated with SF-12v2 physical component summary and mental component summary scores. In a bivariate model, a positive screen for combat-related concussion and persistent

^{***}P<.001.

Table 4. Results of Multivariate Structural Equation Models of Variables Associated With SF-12v2 Health Survey Scores

SF-12v2 Component Summary Scores	β
Physical	
Step 1 ($R^2 = 0.07$, $F = 18.03$, $P < .001$)	
Positive screen for combat-related concussion and persistent	-0.27**
postconcussive symptoms	
Step 2 ($R^2 = 0.26$, $F = 38.17$, $P < .001$)	
Positive screen for combat-related concussion and persistent	-0.09
postconcussive symptoms	
Age	-0.21**
Combat exposure ^a	-0.04
PTSD reexperiencing symptoms	-0.07
PTSD avoidance symptoms	-0.14*
PTSD emotional numbing symptoms	-0.07
PTSD dysphoric arousal symptoms	-0.55***
PTSD anxious arousal symptoms	-0.20***
Mental	
Step 1 ($R^2 = 0.15$, $F = 41.41$, $P < .001$)	
Positive screen for combat-related concussion and persistent	-0.40^{***}
postconcussive symptoms	
Step 2 ($R^2 = 0.68$, $F = 117.27$, $P < .001$)	
Positive screen for combat-related concussion and persistent	0.03
postconcussive symptoms	
College or higher education	0.12*
Rural residence	-0.02
Employed full-time	-0.04
Combat exposure ^a	0.01
PTSD reexperiencing symptoms	-0.27***
PTSD avoidance symptoms	-0.11
PTSD emotional numbing symptoms	-0.56***
PTSD dysphoric arousal symptoms	-0.27***
PTSD anxious arousal symptoms	0.03
^a Compatexposure defined as serving in a direct compator compat	operations role

^aCombat exposure defined as serving in a direct combat or combat operations role. **P*<.05, ***P*<.01, ****P*<.001.

Abbreviations: PTSD = posttraumatic stress disorder, SF-12v2 = 12-Item Short-Form Health Survey, version 2.

Table 5. Results of Multivariate Structural Equation Analyses Examining Relation Between the 5-Factor Model of PTSD Symptoms and Individual SF-12v2 Subscales^a

			Emotional	Dysphoric	Anxious
SF-12v2	Reexperiencing	Avoidance	Numbing	Arousal	Arousal
Physical functioning	-0.06	-0.01	-0.15	-0.52***	-0.08
Role-physical	-0.09	-0.14	-0.14	-0.65***	-0.03
Bodily pain	-0.13	-0.03	-0.16	-0.58^{***}	-0.21*
General health	-0.15	-0.01	-0.12	-0.63***	-0.20*
Vitality	-0.06	-0.09	-0.24**	-0.43***	0.03
Social functioning	-0.19	0.02	-0.65***	-0.36***	-0.20*
Role-emotional	-0.29***	-0.03	-0.44^{***}	-0.39***	0.02
Mental health	-0.25**	-0.10	-0.50^{***}	-0.36***	0.11

^aAll values shown are regression weights (β) that are adjusted for concussion and

persistent postconcussive symptoms, and demographic and clinical variables associated with SF-12v2 PCS scores at the .05 level in bivariate analyses.

P*<.05, *P*<.01, ****P*<.001.

Abbreviations: PTSD = posttraumatic stress disorder, SF-12v2 = 12-Item Short-Form Health Survey, version 2.

postconcussive symptoms was associated negatively with SF12v2 physical component summary scores. However, when PTSD clusters and covariates were added to the model, this association was no longer significant. Posttraumatic stress disorder–related avoidance, dysphoric arousal, and anxious arousal symptoms emerged as significant predictors of SF-12v2 physical component summary scores, with dysphoric arousal symptoms having the largest magnitude association with this outcome. Post hoc analyses revealed that sleep difficulties ($\beta = -0.41$, P < .001) and irritability

and anger outbursts ($\beta = -0.30$, P < .001) were independently associated with these scores, but none of the other avoidance, dysphoric arousal, and anxious arousal symptoms were significant in this analysis (all *P* values > .06).

Combat-related concussion and persistent postconcussive symptoms were also associated negatively with SF-12v2 mental component summary scores in a bivariate model. However, again, when PTSD symptom clusters and covariates were added to the model, this association was no longer significant. Posttraumatic stress disorderrelated reexperiencing, emotional numbing, and dysphoric arousal emerged as significant predictors of SF-12v2 mental component summary scores, with emotional numbing symptoms having the largest magnitude association with this outcome. Post hoc analyses revealed that concentration difficulties ($\beta = -0.24$, P < .001), emotional reactivity to trauma-related cues $(\beta = -0.23, P < .001)$, and detachment $(\beta = -0.21, P < .001)$ P < .001) were independently associated with SF-12v2 mental component summary scores; none of the other reexperiencing, avoidance, emotional numbing, and dysphoric arousal symptoms were significant (all *P* values > .02).

Table 5 shows the associations between the 5-factor model of PTSD symptoms and individual subscales of the SF-12v2. After controlling for combat-related concussion and persistent postconcussive symptoms, screening status, age, and combat exposure, we found that dysphoric arousal symptoms showed the strongest independent associations with the physical functioning, role-physical, bodily pain, general health, and vitality subscales relative to the other 4 clusters. Emotional numbing symptoms showed the strongest independent associations with the social functioning, role-emotional, and mental health subscales relative to the other 4 clusters. Combat-related concussion and persistent postconcussive symptoms screening status was not associated with scores on any of these subscales (all β values < -0.08, all *P* values > .12).

DISCUSSION

To our knowledge, this is the first study to examine how a novel 5-factor model of PTSD symptoms may explain the relation between combat-related concussion with persistent postconcussive symptoms and physical and mental healthrelated quality of life in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn. Results of this study provide greater specificity than previous studies^{13,18,20} in understanding how the heterogeneity of PTSD symptomatology may be related to health-related quality of life in this population.

Veterans who screened positive for combat-related concussion and persistent postconcussive symptoms were more likely to report direct combat exposure, living in a rural area, and screening positive for PTSD and alcohol use problems than those who did not screen positive for combat-related concussion and persistent postconcussive symptoms. A majority (57.3%) of veterans who screened positive for combat-related concussion and persistent postconcussive symptoms also screened positive for PTSD, which is higher than the 40%-44% reported in previous studies^{18,19} but consistent in showing the common comorbidity between concussion/mild traumatic brain injury and PTSD.^{14,15,52,53} This finding underscores the importance of longitudinal studies in this area, as PTSD may confound the putative association between combat-related concussion and persistent postconcussive symptoms/mild traumatic brain injury and functional outcomes.²⁰

Multivariate analyses revealed that veterans who screened positive for combat-related concussion and persistent postconcussive symptoms but not PTSD reported a similar level of physical and mental health-related quality of life compared to those who did not screen positive for combat-related concussion and persistent postconcussive symptoms or PTSD. Veterans who screened positive for combat-related concussion and persistent postconcussive symptoms and PTSD and those who screened positive for PTSD only reported lower vitality, poorer social functioning, greater role limitations because of emotional problems, and poorer mental health than those who did not screen positive for combat-related concussion and persistent postconcussive symptoms or PTSD and those who screened positive for combat-related concussion and persistent postconcussive symptoms only. These findings expand prior research^{13,18,20} by demonstrating that health-related quality of life is more strongly associated with PTSD than combat-related concussion and persistent postconcussive symptoms/mild traumatic brain injury in an ethnoculturally diverse sample of veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn.

Structural equation models further suggested that, after adjustment for combat-related concussion and persistent postconcussive symptoms and demographic and other covariates, PTSD symptoms were independently and differentially associated with physical and mental health-related quality of life. As hypothesized, of the 5 PTSD symptom clusters, dysphoric arousal symptoms were most strongly associated with poorer physical health-related quality of life, while emotional numbing symptoms were most strongly associated with poorer mental health-related quality of life. These findings, which accord with prior studies, 30-36 suggest that dysphoric arousal symptoms, such as sleep and concentration difficulties, and anger/irritability may have a particularly deleterious effect on physical functioning, while emotional numbing symptoms, such as detachment, diminished interest in activities, sense of foreshortened future, and, to a lesser extent, reexperiencing and dysphoric arousal symptoms, may negatively affect mental functioning. Importantly, overlap between emotional numbing symptoms with items that comprise the SF-12v2 mental component summary (eg, feeling downhearted/blue and having low energy) may account, at least in part, for the strong association observed between these symptoms and mental functioning.

These findings have several clinical implications. First, given that PTSD symptoms were independently related to health-related quality of life after adjustment for combatrelated concussion and persistent postconcussive symptoms, screenings for combat-related concussion and persistent postconcussive symptoms/mild traumatic brain injury among veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn should be comprehensive and incorporate screenings for PTSD and related psychological conditions. Second, these results underscore the importance of integrating PTSD treatment with interventions for combat-related concussion and persistent postconcussive symptoms/mild traumatic brain injury, especially in light of evidence suggesting poor overall effectiveness of current interventions for combat-related concussion and persistent postconcussive symptoms/mild traumatic brain injury.54 Third, to improve physical and mental functioning in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn, greater clinical attention-both in assessment as well as in treatment targeting and monitoring-may need to be given to dysphoric arousal and emotional numbing symptoms, which evidenced the strongest associations with these outcomes, respectively.

An important consideration in interpreting the literature on the relation between concussion/mild traumatic brain injury, PTSD, and health and functional outcomes is the role of PTSD as a putative confounder or mediator of observed associations between concussion/mild traumatic brain injury and these outcomes. Confounding can be differentiated from mediation in that the latter implies a temporal sequence from the risk factor (eg, concussion/ mild traumatic brain injury) to the dependent variable (eg, health-related quality of life), whereas the former implies the true causal variable (PTSD) is independently associated with the risk factor and the dependent variable. Given that there is virtually no evidence that concussion/mild traumatic brain injury by itself causes PTSD and that there is considerable overlap between postconcussive and PTSD symptoms (eg, sleep disturbance, anger/irritability, cognitive difficulties),¹⁴ it is likely that PTSD may confound, rather than mediate, the relation between concussion/mild traumatic brain injury and health and functional outcomes.²⁰

This study had several limitations worth noting. First, data on time since combat-related concussion and persistent postconcussive symptoms exposure and frequency of such exposures were not available. Repeated exposure may increase the likelihood of problems with physical functioning, especially if accompanied by additional injury.⁵⁵ Second, while the 5-factor model of PTSD symptoms provided greater specificity in its relation to health-related quality of life, 2 of the factors—avoidance and anxious arousal—are composed of only 2 symptoms. Additional research is needed to examine whether better coverage of these latent

factors of PTSD symptoms yields similar associations with measures of health-related quality of life, as well as how the revised PTSD criteria in the forthcoming *DSM-5*⁵⁶ are related to health-related and other aspects of functioning. Longitudinal studies that employ structured clinical interviews instead of screening instruments will also be helpful in teasing apart these complex associations.

Notwithstanding these limitations, results of this study suggest a novel 5-factor model of PTSD symptoms may provide greater specificity in explaining the association between concussion and persistent postconcussive symptoms and physical and mental health–related quality of life in veterans of Operations Enduring Freedom, Iraqi Freedom, and New Dawn. Further research is needed to examine how treatments for PTSD and concussion/mild traumatic brain injury can be integrated and how treatments for PTSD might be tailored to address specific symptom dimensions of this disorder and ultimately improve functioning and quality of life in this population.

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