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Objective: To empirically identify latent classes of service members according to persistent postconcussive symptom patterns and to characterize the identified classes relative to other postdeployment variables including posttraumatic stress disorder (PTSD) and mild traumatic brain injury (TBI) screening results. Such comparisons may directly inform policy regarding these routine assessments and translate to improved treatment decisions. **Method:** Self-report data were obtained for 12,581 combat-exposed male U.S. Navy and Marine Corps personnel who returned from deployment in 2008–2009 and completed a Post-Deployment Health Assessment (PDHA) and an associated Post-Deployment Health Reassessment (PDHRA). Persistent postconcussive symptoms indicated on the PDHRA were used as manifest variables in a latent class analysis yielding 4 distinct classes: systemic, cognitive/behavioral, comorbid, and nonpresenting. **Results:** Although the nonpresenting class endorsed few or no postconcussive symptoms, the systemic and cognitive/behavioral classes displayed elevated likelihoods of neurological and mental health symptoms, respectively. Members of the comorbid class had an increased probability of reporting a wide range of symptoms across both domains. Characterization of identified classes suggested that class membership may indicate the presence or absence of persistent conditions resulting from head injury and/or mental health issues. Under this assumption, estimated class membership probabilities implied a rate of probable neurological injury among this sample to be 17.9%, whereas the standard assessments aimed at identifying repercussions of mild TBI reported a positive screening rate of only 13.1%. **Conclusions:** Findings suggest that the routinely administered PDHA and PDHRA appear to underestimate the true prevalence of service members experiencing postdeployment health problems. Supplemental items or an alternative screening algorithm incorporating persistent postconcussive symptoms may enable identification of additional cases requiring treatment following return from deployment.

Keywords: traumatic brain injury, posttraumatic stress disorder, latent class analysis, postconcussive symptoms, postdeployment health assessment

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Impact and Implications

- Although overlapping symptoms and high-suspected rates of comorbidity make determination of distinct postdeployment syndromes difficult, this study empirically identifies and characterizes discrete underlying categories of service members suffering from postconcussive symptoms.
- These findings provide support for the existence of three symptomatic classes including a comorbid class of service members experiencing a unique pattern of postconcussive symptoms distinctly different from the symptom patterns exhibited by individuals reporting either exclusively systemic or exclusively cognitive/behavioral complaints.
- Future efforts to provide appropriate prognosis and treatment among combat-exposed service members recently returned from deployment should focus on utilizing general postconcussive symptom items such as auditory concerns and increased irritability alongside standard TBI and PTSD screening results to improve rehabilitation.

Introduction

Traumatic brain injury (TBI) has emerged as the signature injury of the operations in Iraq and Afghanistan, with rates of probable TBI during deployment estimated to exceed 22% (Terrio et al., 2009). Since 2000, greater than 76% of the TBI incidents reported by the Department of Defense were considered mild TBI cases (Defense Medical Surveillance System [DMSS], 2013). The persistent physical, cognitive, and emotional complaints commonly observed following mild TBI have been termed postconcussive symptoms. There is also a high prevalence of postconcussive symptoms among nonclinical, nonconcussed civilian populations (Gouvier, Uddo-Crane, & Brown, 1988; Iverson & Lange, 2003). Furthermore, several postconcussive symptoms, such as irritability and sleep disturbance, are independently asso-

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ciated with mental health disorders. Fox, Lees-Haley, Earnest, and Dolezal-Wood (1995) concluded that although some postconcussive symptoms are associated with head trauma, others appear to be either situational or directly related to psychological distress. This lack of specificity presents a significant challenge when attempting to distinguish between the after effects of mild TBI and other physical and mental ailments arising postdeployment.

To accurately evaluate and treat neurological and mental health conditions among service members returning from deployment, military health care providers need to be aware of the commonly exhibited postconcussive symptom profiles and the rate at which these profiles present and persist within the combat-exposed population. The well-documented overlap in symptoms and the high rate of comorbidity present barriers in linking exhibited symptom patterns to specific etiologies and thereby guiding treatment recommendations. Although numerous studies have attempted to explain symptom patterns relative to repercussions of mild TBI and posttraumatic stress disorder (PTSD), the results of these studies are limited by the instruments used to evaluate the presence or absence of these conditions (Brenner et al., 2010; Iverson, Langlois, McCrea, & Kelly, 2009; Milliken, Auchterlonie, & Hoge, 2007; Schneiderman, Braver, & Kang, 2008). Although diagnosis of moderate and severe TBI or diagnosis occurring at the time of injury is straightforward, mild TBI that goes undiagnosed for weeks or even months after the injury event is subject to recall bias and may be influenced by persistent symptoms stemming from the onset of PTSD, depression, or other physical or mental health disorders (Harvey & Bryant, 2000). Symptoms independently associated with both PTSD and mild TBI, such as trouble sleeping and chronic pain, may also contribute to the development or persistence of health concerns (Nampiamparmpil, 2008; Ruff, Riechers, & Ruff, 2010; Sayer et al., 2009). Creating additional challenges, published findings suggest that incurring a TBI may increase an individual's risk of subsequent PTSD and that PTSD may either mediate or confound the relationship between a reported TBI and postconcussive symptoms (Hoge et al., 2008; Polusny et al., 2011). Several recent studies have noted that while TBI and PTSD are independently associated with postconcussive symptom reporting, when both conditions are present symptoms appear to develop and persist to an even greater extent (Brenner et al., 2010; Macera, Aralis, MacGregor, Rauh, & Galameau, 2012). For these reasons, describing symptom profiles in light of either reported TBI events or PTSD screening results has failed to successfully capture the true underlying distribution of service members exhibiting specific symptoms at similar levels and frequencies.

The screening tools administered to U.S. service members after the completion of each deployment are believed to underestimate the incidence of TBI and to display limited predictive value for PTSD among combat-exposed troops (Drake et al., 2010; Hoge, Auchterlonie, & Milliken, 2006). After reviewing 22 independent studies, researchers from The RAND Corporation concluded that assessment difficulties and broad case definitions have resulted in limited research on the true prevalence of TBI (Tanielian & Jaycox, 2008). Furthermore, they noted that the PTSD case definitions widely used in military studies are based on criteria that have not been appropriately validated and that are likely to exclude significant populations of service members at heightened risk for mental health problems.

Hoge, Goldberg, and Castro (2009) recommended that emphasis be moved away from the diagnosis of mild TBI and PTSD and shifted toward "evidence-based treatments for functional somatic symptoms." Nevertheless, a diagnosis is of value to a clinician interested in educating his or her patient about co-occurring symptoms and determining the appropriate treatment and prognosis. The categorizations resulting from diagnoses are also valuable, if not essential, for research and surveillance, through which population prevalence estimates can be generated. An alternative approach would use persistent symptoms to supplement screening results and event recall when categorizing affected service members into discrete classes for which characteristics such as co-occurring symptoms, population prevalence, and preferred treatment can be established. Potential benefits to this symptoms-based approach would be decreased reliance on self-report of experiences, patient referral only on an as-needed basis, and streamlining of treatment.

When symptoms are reported on a scale, factor analysis is a technique commonly used to map reported symptoms onto continuous latent variables. Latent class analysis is an analogous technique that enables the mapping of dichotomous items, such as the presence or absence of a symptom, to categorical latent variables known as classes. Based entirely on reported symptom patterns, it is therefore possible to empirically divide a subject population into distinct, mutually exclusive subgroups (Lanza, Collins, Lemmon, & Schafer, 2007). Because identification of these homogeneous classes is dependent only on symptom reports, resulting classes can be assumed to reflect the true underlying distribution of syndromes, regardless of screening status or diagnosis.

Numerous studies have evaluated the underlying structure of posttraumatic stress using latent class or factor analysis techniques (Asmundson et al., 2000; Benge, Pastorek, & Thornton, 2009; Breslau, Reboussin, Anthony, & Storr, 2005; Naifeh, Richardson, Del Ben, & Elhai, 2010; Shevlin, Armour, Murphy, Houston, & Adamson, 2010). One study conducted a factor analysis of postconcussive symptoms among a civilian population and evaluated the effect of depression on symptom expression (Herrmann et al., 2009). The sample, however, consisted entirely of patients recruited in a clinical setting and suffering from the repercussions of TBI. Although several studies have succeeded in identifying three distinct clusters of postconcussive symptoms (somatic/sensory, affective/emotional, and cognitive), the factor analysis procedures used in these studies did not allow for the detection of population subgroups defined by differential expression of these symptom clusters (Caplan et al., 2010; Potter, Leigh, Wade, & Fleminger, 2006). Other studies have attempted to identify nonspecific syndromes by means of factor and cluster analyses of symptoms reported by veterans of earlier conflicts (Haley, Kurt, & Hom, 1997; Jones et al., 2002). However, to date, no known study has used standardized postdeployment symptom reports from a large nonclinical sample of military personnel to identify latent population subgroups exhibiting distinct symptom patterns. Identification of subgroups may provide important information for direct application among health care providers who use symptom reports to classify patients when determining the appropriate prognosis, treatment, and rehabilitation plan.

The primary objective of this study is to identify discrete latent classes according to persistent postconcussive symptom patterns reported among a large sample of combat-exposed Navy and

Marine Corps personnel recently returned from deployment. A secondary objective of this study is to characterize identified latent classes by exploring the variables associated with membership in each class. In doing so, this study may improve our understanding of the experiences and disorders that contribute to class membership and may yield further insight into the association of mild TBI and PTSD screening outcomes with class membership and persistent symptom patterns. This approach will inform discussion of whether the current screening algorithms are sufficient and effective in identifying service members likely to need treatment for persistent postdeployment symptoms.

Method

Participants

The Post-Deployment Health Assessment (PDHA) is administered to all service members around the time of return from deployment (Deployment Health Clinical Center [DHCC], DD Form 2796, 2008). The PDHA is administered in an attempt to review each service member's current physical and mental health and to assess for common postdeployment psychosocial problems. The questionnaire portion of the PDHA contains brief validated screening instruments, a separate section for the report of current symptoms, and a number of items inquiring about a wide range of demographic characteristics, environmental exposures, and combat experiences. The Post-Deployment Health Reassessment (PDHRA) contains similar items as the PDHA and is given approximately 3 to 6 months after deployment end (DHCC, DD Form 2900, 2008). Beginning in January 2008, updated versions of both the PDHA and PDHRA were introduced containing additional items used to evaluate a service member's potential risk of having experienced a mild TBI (hereafter referred to as TBI).

For this study, all Navy and Marine Corps PDHA and PDHRA forms completed during 2008–2009 were obtained from the Electronic Pre- and Post-Deployment Health Assessment Database maintained by the Navy and Marine Corps Public Health Center. Inclusion criteria were deployment to Iraq, Afghanistan, or Kuwait (as indicated on the PDHA) and a PDHRA completed between 30 and 365 days following PDHA administration. Additionally, participants were required to have responded "yes" to at least one of three combat exposure items on the PDHA concerning (a) encountering dead or wounded people, (b) engaging in direct combat and discharging a weapon, and (c) feeling in great danger of being killed during deployment. The combat exposure criterion ensured that the study sample was composed of individuals at risk for the onset of PTSD and TBI-related symptoms (Smith et al., 2008). Combat deployments are rare among female service members. Because women made up only a small percentage of the potential study sample and are believed to present for certain mental health disorders at different rates than men, women were excluded (Breslau & Anthony, 2007). This study was approved by the Naval Health Research Center Institutional Review Board (Protocol NHRC.2009.0020).

Measures

Manifest variables. Manifest variables used in the latent class analysis were derived from PDHRA symptoms. Of the 24 symp-

toms included on the PDHRA, 12 are generally considered to be postconcussive symptoms (Ryan & Warden, 2003). Specifically, dichotomous responses of yes or no to experiencing each of the following postconcussive symptoms at the time of PDHRA administration were provided to the latent class analysis procedure: (a) bad headaches; (b) generally feeling weak; (c) numbness or tingling in hands or feet; (d) trouble hearing; (e) ringing in the ears; (f) dimming of vision like the lights were going out; (g) dizzy, light headed, passed out; (h) problems sleeping or still feeling tired after sleeping; (i) increased irritability; (j) trouble concentrating, easily distracted; (k) forgetful or trouble remembering things; and (l) hard to make up your mind or make decisions. Postconcussive symptoms were used from the PDHRA, rather than the PDHA, for two main reasons: (a) most individuals who sustain a TBI experience symptoms during the initial month postinjury; these symptoms, however, are believed to resolve within 3 months in approximately two thirds of affected service members (McAllister & Arciniegas, 2002); and (b) PTSD symptom reporting is known to be higher on the PDHRA than the PDHA, denoting symptom development or worsening following return from deployment (Milliken et al., 2007). According to the *Diagnostic and Statistical Manual, Fourth Edition (DSM-IV)*, symptoms of PTSD must persist for a minimum of 1 month before an individual can be eligible for a diagnosis. It is therefore reasonable to consider symptoms at the later assessment. In summary, to obtain latent classes representing only those individuals for whom persistent symptoms would necessitate treatment, responses from the PDHRA were used.

Demographic variables. Demographic variables included age, military pay grade, and branch of service. All demographic variables were obtained from PDHA records and reflect the service member's status at deployment end. Age (< 25, 25–29, 30–39, ≥ 40 years), military rank (junior enlisted, senior enlisted, officer/warrant officer), and branch of service (Marine Corps, Navy) were analyzed as categorical variables.

Postdeployment assessment variables. To characterize identified classes, variables were created based on service member responses to items on the PDHA and PDHRA instruments. Although endorsement of at least one combat exposure item on the PDHA was required for inclusion, type of combat exposure was examined by analyzing each of the three items separately. Additionally, a single variable was created to indicate the total number of combat exposure items endorsed (1–3). On both questionnaires, service members were asked to rate their overall health during the past month as *Excellent*, *Very Good*, *Good*, *Fair*, or *Poor*. A response of *Fair* or *Poor* at either administration was analyzed in this study. On the PDHA, respondents were also given the opportunity to indicate if they were wounded, injured, assaulted, or otherwise hurt (*yes* or *no*) and whether they had spent 1 or more nights in the hospital (*yes* or *no*) during their most recent deployment.

In this study, service members were considered to have screened positive for PTSD, TBI, and depression if they screened positive for the condition on either or both assessments. We felt that it was important to consider positive screens on either the PDHA or the PDHRA for these conditions because an aim of this study was to assess the proportion of service members that would have been identified at either time point using the routine screening mechanisms and to compare this proportion with the distribution of

identified latent classes. Items from the Primary Care 4-item Post-Traumatic Stress Disorder screen (PC-PTSD) are included on both the PDHA and the PDHRA. Respondents were considered to have screened positive for PTSD if they answered yes to at least two of the four questions about having recently experienced symptoms related to the four underlying domains of PTSD (reexperiencing, emotional numbing, avoidance, and hyperarousal; Asmundson et al., 2000; King, Leskin, King, & Weathers, 1998). The PC-PTSD has been validated among active-duty service members returning from deployment and a 2-item cutoff has been recommended and used in previous studies (Bliese et al., 2008; Hoge et al., 2006). The 2-item cutoff is believed to identify cases with a sensitivity of 0.91 and a specificity of 0.72 (Prins et al., 2004).

As part of the TBI screen, service members were asked on both assessments whether they experienced a blast or explosion, vehicular accident/crash, fragment or bullet wound above the shoulders, fall, or other injury to the head during deployment. Following a positive response to one of the previous items, service members were asked whether they immediately “lost consciousness or got ‘knocked out,’” “felt dazed, confused or ‘saw stars,’” or “didn’t remember the event.” Based on the guidance distributed to military health care providers (DHCC, ASD (HA), 2008), and in accordance with established criteria (American Congress of Rehabilitative Medicine, 1993), service members who provided positive responses to at least one item on the injury question and at least one alteration/loss of consciousness item were considered to have screened positive for a potential TBI (Hoge et al., 2008).

A 2-item depression screen derived from the validated Patient Health Questionnaire is included in both assessments (Kroenke, Spitzer, & Williams, 2003). The items ask service members to indicate a categorical number of days during which they were bothered by “little interest or pleasure in doing things” (anhedonia) and “feeling down, depressed, or hopeless” (depressed mood) over the past month. A response of *more than half the days* or *every day* on either of the items resulted in a positive screen for potential depression (Milliken et al., 2007).

Analyses

A latent class analysis was conducted with 12 dichotomous manifest variables indicating service member responses of yes or no to experiencing each of 12 postconcussive symptoms at the time of PDHRA administration. Based on the number of manifest variables, models of between two and eight latent classes were evaluated. Model fit was assessed using Akaike information criterion (AIC; Akaike, 1974), Bayesian information criterion (BIC) (Schwarz, 1978), and special consideration was given to sample size-adjusted BIC (Sclove, 1987). Parsimony (degree of improvement compared with a simpler model) and interpretability of the results were important factors when deciding on the number of classes to include.

For each class, posterior probabilities of membership and item response probabilities were generated. According to the maximum-probability assignment rule, each subject was assigned to the class for which his estimated class membership probability was highest. To evaluate classification quality and the likelihood of misclassification, mean class membership probabilities were calculated for participants in each class. The underlying population distribution of class membership was also estimated.

To characterize identified latent classes, demographic variables and PDHA/PDHRA responses were tested for association with class membership among all participants in the sample. Chi-square tests were used to determine distributional differences between classes. A Bonferroni-adjusted 2-sided p value of 0.008 was used to account for the six different hypothesis tests conducted on various combinations of classes while maintaining an overall 2-sided p value of 0.05. Differences across classes in the mean numbers of postconcussive symptoms indicated on the PDHA and PDHRA were tested using an analysis of variance procedure with Bonferroni post hoc adjustments. A chi-square test was implemented to compare the distribution of latent classes with the distribution of TBI and PTSD screening results on the PDHA and PDHRA.

For each class, a multiple logistic regression model was constructed to predict the outcome of membership in the given class relative to membership in Class 4, the class displaying the lowest rate of symptom reporting. Adjusted odds ratios and 95% CIs were produced to determine the unique ability of PTSD, depression, and TBI screening results to predict membership in Classes 1, 2, or 3, relative to Class 4. In all three models, we controlled for significant demographic and deployment-related characteristics (age, military rank, service branch, deployment location, self-rated health, injury status, type of combat experienced, and hospitalization).

All statistical analyses were performed using SAS software, version 9.2 (SAS Institute Inc., Cary, North Carolina). For latent class analyses, SAS PROC LCA, version 1.2.5 was used (PROC LCA; Lanza et al., 2007).

Results

Analysis yielded four classes with distinct symptom patterns. Although the 5-class model yielded moderately lower AIC and BIC statistics, a clear leveling off in AIC and BIC was observed after the 4-class model with relatively minor decreases following the addition of Classes 5–8. Further, the 5-class model resulted in two classes with similar item response distributions, differing only in the magnitude of the probabilities, rather than the symptom pattern. Thus, based on the objectives of this study, the 4-class model was selected for its ability to identify distinct item response probability profiles. Based on these profiles, Classes 1–4 were assigned the following names: systemic, cognitive/behavioral, comorbid, and nonpresenting. Latent class analysis results indicated that members of the systemic class had an elevated likelihood (> 0.25 probability) of reporting persistent bad headaches, trouble hearing, ringing in the ears, problems sleeping or still feeling tired after sleeping, and increased irritability (see Figure 1). Members of the cognitive/behavioral class had a high likelihood of indicating persistent problems sleeping or still feeling tired after sleeping, trouble concentrating or being easily distracted, forgetfulness or trouble remembering things, difficulty making decisions, and increased irritability. Members of the comorbid class had an increased likelihood of endorsing all of the same symptoms as members of the systemic class in addition to generally feeling weak, numbness or tingling in hands or feet, trouble concentrating or being easily distracted, forgetfulness or trouble remembering things, and difficulty making decisions. For each of the 12 items,

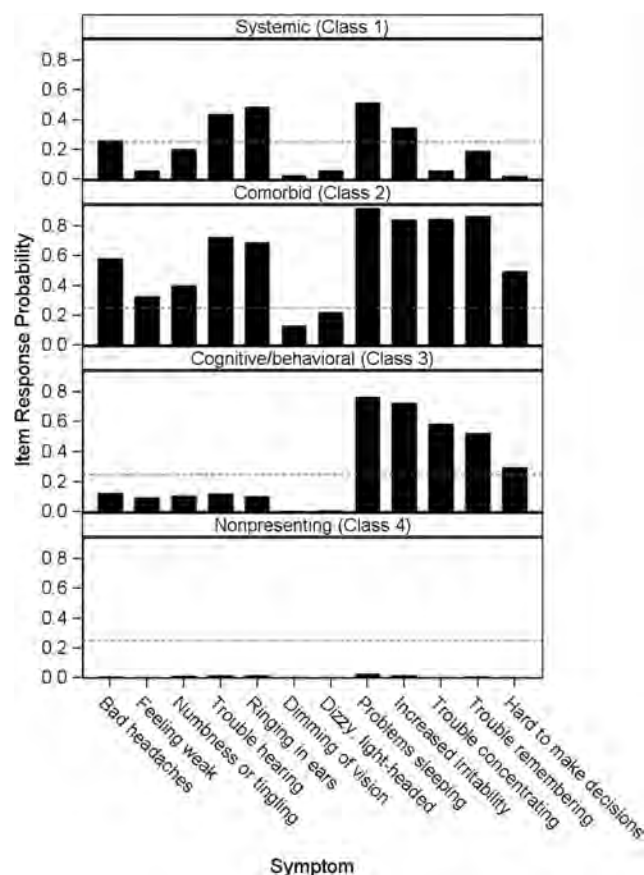


Figure 1. Estimated item response probabilities across postconcussive symptoms for the four identified classes.

members of the nonpresenting class were highly unlikely (< 0.02 probability) to have responded positively.

Assignment of individuals to unique classes using the maximum-probability assignment rule yielded mean class membership probabilities of 0.87 for systemic, 0.76 for cognitive/behavioral, 0.88 for comorbid, and 0.97 for nonpresenting, signaling relatively good classification quality. Among service members in the cognitive/behavioral class, the probability of misclassification into the systemic class was estimated to be 0.16, suggesting that some members of the cognitive/behavioral class displayed symptom patterns partially resembling those exhibited by members of the systemic class. All remaining posterior probabilities of membership among classes to which participants were not assigned were < 0.10 , indicating a low expected rate of misclassification.

In comparing demographic characteristics across classes, members of the cognitive/behavioral class were older and more likely to be Navy personnel relative to members of the systemic class and members of the nonpresenting class (see Table 1). Relative to individuals in the cognitive/behavioral and nonpresenting classes, individuals belonging to the systemic and comorbid classes were more likely to have deployed to Afghanistan and less likely to have deployed to Iraq. Twelve percent of nonpresenting class members were officers compared with only 8.1% in both the systemic and

cognitive/behavioral classes and 5.7% in the comorbid class. Effect sizes corresponding to the p values in Table 1 are available in the online supplemental materials in Table 1.

Relative to participants classified in the cognitive/behavioral and nonpresenting classes, those belonging to the systemic and comorbid classes were significantly more likely to have engaged in direct combat where they discharged a weapon (see Table 2). Although the percentage of respondents indicating fair or poor self-rated health among systemic and cognitive/behavioral classes was similar, the percentage was significantly higher among individuals in the comorbid class and significantly lower among persons in the nonpresenting class. With respect to injuries incurred during deployment and TBI screening results, all four classes exhibited significantly different response rates, with the highest percentage belonging to the comorbid class, followed in order by the systemic, cognitive/behavioral, and nonpresenting classes. Seventy-seven percent of participants within the comorbid class and 57% of participants in the cognitive/behavioral class screened positive for PTSD. Depression screening rates were also high among these two classes, with 62% of comorbid class members and 45% of cognitive/behavioral class members meeting criteria. Participants in the nonpresenting class reported experiencing an average of less than one postconcussive symptom at the time of both the PDHA and the PDHRA. By comparison, participants in the comorbid class endorsed an average of 3.4 symptoms on the PDHA and 7.2 symptoms on the PDHRA. The nonpresenting class was the only class in which the mean number of postconcussive symptoms indicated was less on the PDHRA than the PDHA. Effect sizes for these pairwise class comparisons can be found in the online supplemental materials in Table 2.

Adjusted odds ratios derived from the three multiple logistic regression models constructed to predict membership in the systemic, comorbid, and cognitive/behavioral classes (relative to the nonpresenting class) are shown in Table 3. Respondents screening positive for PTSD, and those screening positive for PTSD were at significantly increased (adjusted) odds of being members of the systemic, comorbid, and cognitive/behavioral classes. Among these comparisons, adjusted odds ratios were highest for positive PTSD and depression screens predicting the probability of membership in the comorbid (6.77 and 3.89, respectively) and cognitive/behavioral (4.26 and 3.03, respectively) classes. Screening positive for TBI significantly increased the adjusted odds of membership in both the systemic (1.78) and comorbid (2.43) classes, although to a lesser extent.

Table 4 compares the distribution of class membership probabilities among the four identified latent classes and the distribution of probable TBI and PTSD among all combat-deployed service members, as estimated by the PDHA/RA screening tools applied to this study sample. In general, the distribution generated by the latent class analysis procedure resembles the expected distribution of TBI, PTSD, and comorbid populations according to current published research (Tanielian & Jaycox, 2008; Terrio et al., 2009). The PDHA/RA screening results, however, appear to classify a smaller percentage of study participants into the TBI and comorbid groups, relative to published statistics and estimates produced by the latent class analysis procedure (obtained by combining systemic and comorbid classes). The distribution across groups differed significantly between the two classification methods ($p < .0001$). The relatively high percentage of respondents who

Table 1
Demographic and Deployment-Related Characteristics by Class Membership (N = 12,581)

	Systemic (n = 1,265) n (%)	Cognitive/behavioral (n = 867) n (%)	Comorbid (n = 665) n (%)	Nonpresenting (n = 9,784) n (%)	p value
Age, years					<0.0001 ^{a-e}
<25	705 (55.7)	408 (47.1)	369 (55.5)	5,447 (55.7)	
25–29	225 (17.8)	182 (21.0)	129 (19.4)	1,916 (19.6)	
30–39	226 (17.9)	194 (22.4)	97 (14.6)	1,836 (18.8)	
≥40	109 (8.6)	83 (9.6)	70 (10.5)	585 (6.0)	
Rank					<0.0001 ^{b,d,e}
Junior enlisted	860 (68.0)	593 (68.4)	488 (73.4)	6,548 (66.9)	
Senior enlisted	302 (23.9)	204 (23.5)	139 (20.9)	2,065 (21.1)	
Officer/Warrant Officer	103 (8.1)	70 (8.1)	38 (5.7)	1,171 (12.0)	
Service branch					<0.0001 ^{a,b,c,e}
Marine Corps	999 (79.0)	555 (64.0)	519 (78.1)	7,286 (74.5)	
Navy	266 (21.0)	312 (36.0)	146 (22.0)	2,498 (25.5)	
Deployment location					<0.0001 ^{b,c,d}
Afghanistan	365 (28.9)	218 (25.1)	217 (32.6)	2,496 (25.5)	
Iraq	874 (69.1)	624 (72.0)	436 (65.6)	6,926 (70.8)	
Kuwait	26 (2.1)	25 (2.9)	12 (1.8)	362 (3.7)	

Note. Effect sizes presented in Supplemental Table 1.

^a Systemic vs. Cognitive/behavioral was significantly different ($p < .05$, Bonferroni adjustment $p < .008$). ^b Systemic vs. Nonpresenting. ^c Comorbid vs. Cognitive/behavioral. ^d Comorbid vs. Nonpresenting. ^e Cognitive/behavioral vs. Nonpresenting.

screened positive for PTSD on the PDHA or PDHRA is due to use of the 2-item cutoff, which is known to favor sensitivity (Bliese et al., 2008).

Discussion

To our knowledge, this is the first study to conduct a latent class analysis using postconcussive symptoms reported by combat-

exposed service members. Our study successfully identified four latent classes that may be related to underlying levels of TBI, PTSD, and comorbidity. Members of these latent classes reported deployment experiences and demographic characteristics congruent with an elevated likelihood of head injury and mental health repercussions, the presence and absence of which was approximated by latent class membership. Members of the systemic and

Table 2
Postdeployment Health Assessment (PDHA) and Postdeployment Health Reassessment (PDHRA) Responses by Class Membership (N = 12,581)

	Systemic (n = 1,265) n (%)	Cognitive/behavioral (n = 867) n (%)	Comorbid (n = 665) n (%)	Nonpresenting (n = 9,784) n (%)	p value
Combat exposure					
See dead or wounded	828 (65.5)	530 (61.1)	436 (65.6)	6,686 (68.3)	<0.0001 ^f
Engaged in direct combat	279 (22.1)	144 (16.6)	160 (24.1)	1,853 (18.9)	0.0001 ^{b,c,d,e}
Feel in great danger	916 (72.4)	637 (73.5)	537 (80.8)	5,585 (57.1)	
Total number					<0.0001 ^{c,d,e}
1	709 (56.1)	533 (61.5)	331 (49.8)	6,501 (66.5)	
2	354 (28.0)	224 (25.8)	200 (30.1)	2,226 (22.8)	
3	202 (16.0)	110 (12.7)	134 (20.2)	1,057 (10.8)	
Fair or poor self-rated health	455 (36.0)	294 (33.9)	365 (54.9)	1,263 (12.9)	<0.0001 ^{a,c,d,e,f}
Injured during deployment	579 (45.8)	346 (39.9)	376 (56.5)	2,184 (22.3)	<0.0001 ^g
Hospital stay during deployment	63 (5.0)	41 (4.7)	53 (8.0)	222 (2.3)	<0.0001 ^{c,e,f}
PTSD on PDHA or PDHRA	485 (38.3)	496 (57.2)	512 (77.0)	1,515 (15.5)	<0.0001 ^g
Depression on PDHA or PDHRA	352 (27.8)	393 (45.3)	413 (62.1)	1,263 (12.9)	<0.0001 ^g
TBI on PDHA or PDHRA	317 (25.1)	171 (19.7)	289 (43.5)	875 (8.9)	<0.0001 ^g
	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>	
Number of symptoms					
PDHA	1.85 ± 2.3	1.76 ± 2.3	3.35 ± 3.2	0.67 ± 1.5	<0.0001 ^{a,c,d,e,f}
PDHRA	3.09 ± 1.1	3.36 ± 1.2	7.18 ± 1.6	0.10 ± 0.3	<0.0001 ^g

Note. PTSD = posttraumatic stress disorder; TBI = traumatic brain injury. Effect sizes presented in Supplemental Table 2.

^a Systemic vs. Comorbid was significantly different ($p < .05$, Bonferroni adjustment $p < .0083$). ^b Systemic vs. Cognitive/behavioral ($p < .008$). ^c Systemic vs. Nonpresenting. ^d Comorbid vs. Cognitive/behavioral. ^e Comorbid vs. Nonpresenting. ^f Cognitive/behavioral vs. Nonpresenting. ^g All pairwise class comparisons.

Table 3
Multiple Logistic Regression Adjusted Odds Ratios Reflecting the Relative Odds of
Class Membership

	Systemic ^a Class 1 (<i>n</i> = 1,265) OR [95% CI]	Cognitive/behavioral ^a Class 3 (<i>n</i> = 867) OR [95% CI]	Comorbid ^a Class 2 (<i>n</i> = 665) OR [95% CI]
PTSD on PDHA or PDHRA	1.98 [1.72–2.29]*	4.26 [3.61–5.03]*	6.77 [5.45–8.41]*
Depression on PDHA or PDHRA	1.52 [1.30–1.77]*	3.03 [2.56–3.59]*	3.89 [3.18–4.77]*
TBI on PDHA or PDHRA	1.78 [1.51–2.11]*	1.21 [0.98–1.50]	2.43 [1.95–3.02]*

Note. CI = confidence interval; PDHA = Post-Deployment Health Assessment; PDHRA = Post-Deployment Health Reassessment; PTSD = posttraumatic stress disorder; OR = odds ratio; TBI = traumatic brain injury. All models adjusted for age, military rank, service branch, deployment location, type of combat exposure, self-rated health, injury during deployment, hospitalization, and screening variables shown.

^a Class 4 (Nonpresenting) is reference class.

* Significant at the $p < .05$ level.

comorbid classes were more likely to be enlisted, Marines, and to have deployed to Afghanistan, all characteristics known to increase risk of experiencing a TBI. In fact, these classes of service members also reported more combat exposures on average and were more likely to have been injured or stayed in the hospital during the previous deployment. In contrast, these demographic risk factors were not observed among members of the cognitive/behavioral class who were more likely to screen positive for PTSD and depression relative to members of the systemic and nonpresenting classes.

The latent class item response probabilities along with the demographic descriptions presented here should be used to guide clinicians in classifying patients into systemic, cognitive/behavioral, comorbid, and nonpresenting symptom groupings for planning and providing appropriate treatment. To improve health outcomes, patients should be informed that the symptom profile they are exhibiting is one of a series of commonly observed responses to the traumatic injury and/or stress associated with combat deployment, and positive expectations of recovery should be conveyed (Bryant, 2008; Hoge et al., 2009). Incorporation of these latent class results into the clinical setting could thereby serve to normalize symptoms experienced by service members and direct symptomatic individuals to more indicated and targeted interventions. This approach could potentially mitigate the number of

service members presenting with iatrogenic disorders observed among those who screen positive or receive a diagnosis of PTSD or TBI. Additionally, clinicians and policymakers can benefit from the predicted class membership distribution when determining the quantity and type of resources required at military and veteran medical treatment facilities.

The empirical procedure used in this study resulted in a unique class of individuals experiencing primarily neurological postconcussive symptoms. Initial research concluded that the strongest factor independently associated with postconcussive symptoms was PTSD (Schneiderman et al., 2008), and after accounting for mental health disorders, such as depression and PTSD, headache was the only physical health symptom significantly associated with TBI and only among those who had lost consciousness (Hoge et al., 2008). Several recent studies, however, have used larger samples to independently associate reported TBI with the development of postconcussive symptoms (Brenner et al., 2010; Macera et al., 2012; Vanderploeg, Belanger, & Curtiss, 2009). In addition to headaches, the findings from the present study suggest that auditory concerns, sleeping problems, and irritability are all symptoms that persist among service members who do not necessarily present with significant stress disorder symptoms and may be suffering from the repercussions of TBI in the absence of PTSD. These general postconcussive symptoms, if further incorporated into the existing screening instrument, could potentially increase the utility of the tool for identifying service members experiencing neurological and/or mental health concerns during the months following deployment and referring these individuals into appropriate treatment programs.

The use of postconcussive symptoms to identify participants with neurological and psychological disorders has been criticized on the premise of high base rates for such symptoms among the general population and the population sustaining nonhead injuries (Dikmen & Levin, 1993; Gouvier et al., 1988; McAllister & Arciniegas, 2002; Satz et al., 1999). On the contrary, results from our study support the existence of a distinct population of combat-exposed service members who report few or no postconcussive symptoms months after deployment. Regardless of the potential inclusion of men who sustained physical nonhead injuries in the nonpresenting class, considerable differences were seen in postconcussive symptom reporting within this class, relative to the

Table 4
Class Membership Probabilities Among the Identified Classes
and Screening Rates For TBI and PTSD

Latent Class Analysis	%	PDHA and PDHRA Screening rates ^a	%
Nonpresenting	75.31	No TBI and no PTSD	69.83
Systemic	12.52	TBI only	6.26
Cognitive/behavioral	6.76	PTSD only	17.04
Comorbid	5.41	Both TBI and PTSD	6.87

Note. CI = confidence interval; PDHA = Post-Deployment Health Assessment; PDHRA = Post-Deployment Health Reassessment; PTSD = posttraumatic stress disorder; TBI = traumatic brain injury.

^a Service members were considered to have screened positive for PTSD and TBI if they screened positive for the condition on either or both assessments.

* Significant chi-square p -value < 0.0001 .

three other classes. Health care providers conducting PDHRA interviews should thoroughly evaluate service members who report multiple postconcussive symptoms because these individuals are likely to be members of the systemic, cognitive/behavioral, or comorbid classes defined in this study and could possibly be experiencing the after effects of TBI and/or the development of PTSD. Similarly, because symptoms are expected to resolve from the PDHA to the PDHRA only among the nonpresenting group, patients who do not demonstrate improvement should be considered for membership in one of the symptomatic classes. This is an especially important consideration when evaluating service members reporting TBI-related symptoms that are expected to resolve in the months following the injury event. This implies that membership in the systemic group may indicate a different pathology than the typical TBI diagnosis, but one which persists and warrants specialized treatment.

One study noted that the Brief Traumatic Brain Injury Screen (BTBIS), from which the PDHA and PDHRA screening instruments are derived, resulted in the probable underidentification of TBI incidence among a large cohort of Marines returning from a combat deployment (Drake et al., 2010). In support of this finding, only 13.13% of the sample in the present study screened positive for TBI on either the PDHA or the PDHRA compared with 17.93% who were identified by the latent class analysis as experiencing persistent neurological symptoms typical of a head injury (based on combined membership percentages in the systemic and comorbid classes; $p < .0001$). These higher rates are also more similar to hypothesized population-wide TBI incidence rates. Moreover, the positive TBI screening rate among this sample would have been even lower had screening results from only one of the two assessments been considered. These findings provide support for the ability of this latent class approach, based only on postconcussive symptoms, to identify patients who would have been missed using the standard screening tools. Importantly, the routinely administered postdeployment TBI screen appears to underestimate the true prevalence of neurological conditions among this population and policymakers should note that alternative items and/or screening algorithms relying on a general set of postconcussive symptoms may increase identification of individuals with postconcussive concerns that require treatment.

Large-scale implementation of PTSD screening among service members recently returned from deployment is important for early identification, effective intervention, tracking prevalence rate changes, and assessing service needs. Nevertheless, some researchers have expressed concerns about the relatively small number of service members requiring prompt psychological care relative to the large number screening positive on the PDHA and, to a greater extent, the PDHRA (Gates, Holowka, & Rosen, 2012; Rona, Hyams, & Wessely, 2005). The approach presented here may provide for a more accurate identification of service members requiring psychological treatment and demonstrate substantially increased specificity relative to the 2-item PC-PTSD screen. Prospective studies should be designed to evaluate whether a symptoms-based approach such as the one presented here can effectively reduce long-term psychiatric morbidity in the population of active duty service members.

Our results suggest that membership in the comorbid class is associated with the elevated expression and persistence of both systemic and cognitive/behavioral symptoms. Our study also

found a strong association between membership in the comorbid class and receipt of a positive depression screen. Even after accounting for PTSD, service members at risk for depression had 3.9 times the odds of belonging to the comorbid class relative to the nonpresenting class. Membership in the comorbid class could be dependent upon neurological injury in combination with either depression or PTSD. Results from a study by Hoge et al. (2008) suggest that both PTSD and depression may act as mediators of the relationship between TBI and the development of postdeployment somatic symptoms. The overlap in symptoms experienced by patients diagnosed with PTSD and depression has been well documented. The low granularity of the symptom descriptions used in this study may not have allowed for accurate discernment between these frequently co-occurring disorders. Following TBI, one study noted that depression may heighten patient perception of postconcussive symptoms thereby inflating symptom reporting rates among individuals suffering from depression (Herrmann et al., 2009). In examining the latent structure of PTSD, Naifeh, Richardson, Del Ben, and Elhai (2010) recently identified a significant association between depression and membership in a class of military veterans reporting relatively severe PTSD symptoms. Although additional longitudinal research is needed, our results support the hypothesis that depression is responsible for increases in the range and rate of symptom reporting among comorbid service members. As many researchers have stated, the true relationship between TBI, PTSD, and depression is likely complex and should be an area for continued research.

We anticipate that an important implication of the findings presented here will be an increase in awareness among military health providers that a one-size-fits-all approach to treatment may be ineffective among this population. This heightened awareness, in conjunction with future research and evaluation efforts, could increase the percentage of symptomatic service members directed into effective and appropriate treatment programs. Although PTSD treatment programs have been widely executed and evaluated, limited research had been conducted to develop and assess mild TBI and comorbid treatments implemented among active duty service members recently returned from deployment (Carlson et al., 2011). Among veterans presenting with mild TBI, psychoeducational interventions in combination with targeted symptom treatment following a cognitive-behavioral model has been shown to be effective (Belanger, Uomoto, & Vanderploeg, 2009). Integrative rehabilitation programs that guide service members to specific treatment for symptoms such as headaches, insomnia, and memory problems while recognizing the overarching injury and promoting a gradual return to premorbid activities are likely to be most effective among active duty service members with persistent symptoms.

There are several limitations of this study that should be noted. Because our study included only male Marine Corps and Navy personnel, it is possible that the identified classes and the characteristics attributed to these classes are not representative of all deployed military personnel. Recent studies have concluded that longitudinal changes in postconcussive symptoms are not independent of underlying neurological and psychological conditions (Macera et al., 2012; Polusny et al., 2011). However, the manifest variables used in our study were derived from service member reports of having experienced postconcussive symptoms approximately 3–6 months following return from deployment. The results

of the present study are therefore generalizable only within a similar postdeployment time frame. Service member responses to the postconcussive symptom and TBI and PTSD screening items included on current assessments may be influenced by a number of career and personal motivations. An individual may censor his responses to the TBI and PTSD screening items in an attempt to remain stationed with his unit, ensure a rapid return home, or avoid receiving a stigmatizing and potentially career-altering diagnosis. A service member may alternatively endorse screening items at a heightened rate if attempting to account for negative behavioral events, avoid a future deployment, justify the onset of symptoms, or obtain a higher medical disability rating (Drake et al., 2010). This reporting bias may be a limitation among the general symptom items as well and could potentially affect the results presented here. Although previous research has suggested that there is an association between condition severity and postconcussive symptom reporting, the findings of this study were not discussed in light of either PTSD or TBI severity (Schneiderman et al., 2008). Because service member medical records were not accessed in this study, co-occurring physical nonhead injuries, diseases, and pre-existing mental health disorders that could potentially affect postconcussive symptom patterns were not accounted for in the present findings. Furthermore, although characterization of the three identified symptomatic classes appeared to reflect TBI and PTSD presence/absence, these classes could also be representative of various other conditions including somatoform disorders, central nervous system damage, and depression. The 2-item criterion for probable PTSD was used instead of the 3-item criterion in examining the distribution of PDHA and PDHRA screening results thus potentially increasing our number of false positives. In consequence, the prevalence of PTSD estimated using the screening instruments may not be directly comparable with the predictions obtained from the latent class analysis and previously published estimates. The results presented here reflect the symptom pattern distribution among a large sample. Nevertheless, the reliability of the latent class solution obtained in this study has not been explored across different samples of the target population. Future studies into the reliability and validity of the model should be undertaken. Our findings should be interpreted with these limitations in mind.

The results of our study provide support for the use of self-reported symptoms to empirically identify distinct systemic, cognitive/behavioral, and comorbid syndromes. The item response patterns presented here can be used to assist health practitioners in evaluating their patients for membership in a given class, thereby providing them additional information to better determine the appropriate treatment plan. Findings of our study support the need for multidisciplinary evaluation and treatment of service members returning from combat deployments.

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14. ABSTRACT The objective of this study was to empirically identify latent classes according to persistent postconcussive symptom patterns among 12,581 combat-exposed male service members. A secondary objective was to characterize identified classes to better understand the experiences and disorders associated with class membership. Persistent postconcussive symptoms reported by Marines and sailors on the Post-Deployment Health Reassessment were used as manifest variables in a latent class analysis, yielding 4 distinct classes: systemic, co-morbid, psychological, and nonpresenting. While the nonpresenting class endorsed few or no postconcussive symptoms, members of the comorbid class had an increased likelihood of reporting a wide range of symptoms. Characterization of the 4 classes suggested that these classes approximate populations defined by the presence or absence of traumatic brain injury and/or posttraumatic stress disorder. These findings can be used to guide clinicians in categorizing patients into systemic, psychological, and comorbid symptom groupings to facilitate planning and providing of the appropriate treatment.					
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