

Predeployment Sleep Duration and Insomnia Symptoms as Risk Factors for New-Onset Mental Health Disorders Following Military Deployment

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Study Objectives: To evaluate predeployment sleep duration and insomnia symptoms in relation to the development of mental health symptoms.

Design: Longitudinal cohort study.

Setting: The Millennium Cohort Study survey is administered via a secure website or US mail.

Participants: Data were from 15,204 participants who completed their first deployment between the submissions of 2 consecutive Millennium Cohort questionnaires (2001-2008).

Interventions: N/A.

Measurements and Results: Using self-reported data from the Millennium Cohort Study we evaluated the association of predeployment sleep duration and insomnia symptoms on the development of new-onset mental disorders among deployers. Multivariable logistic regression was used to estimate the odds of developing posttraumatic stress disorder (PTSD), depression, and anxiety, while adjusting for relevant covariates including combat-related trauma. The study outcomes were assessed using validated instruments, including the PTSD checklist-civilian version, and the PRIME-MD Patient Health Questionnaire. We identified 522 people with new-onset PTSD, 151 with anxiety, and 303 with depression following deployment. In adjusted models, combat-related trauma and predeployment insomnia symptoms were significantly associated with higher odds of developing posttraumatic stress disorder, depression, and anxiety postdeployment.

Conclusions: Sleep characteristics, especially insomnia symptoms, are related to the development of mental disorders following military deployments. Assessment of insomnia symptoms predeployment may help to better identify those at highest risk for subsequent adverse mental health outcomes.

Keywords: Stress disorders, post-traumatic, anxiety, depression, sleep

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INTRODUCTION

Military personnel, particularly those engaged in combat situations, are at increased risk for developing mental disorders such as posttraumatic stress disorder (PTSD) and depression.¹⁻³ Postdeployment assessments of personnel returning from Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF) found that 20.3% of active duty and 42.4% of reserve soldiers reported significant mental health symptoms.¹ Insomnia symptoms often occur in association with military deployment, with combat-related trauma and the presence of mental health symptoms substantially increasing the likelihood of difficulties with sleep.⁴ While it is reasonable to expect that insomnia symptoms are a consequence of these situations, there is reason to believe that preexisting insomnia may increase the

risk of developing mental disorders in response to extremely stressful situations such as combat.^{5,6} Longitudinal studies have demonstrated that insomnia confers significant risk for the development of new-onset major depressive disorder and anxiety disorders, including PTSD.⁷⁻¹⁹ Insomnia is both a symptom and a risk factor for mental illness and may present a modifiable target for intervention among military personnel.

The Millennium Cohort Study²⁰ provides a unique ability to enhance understanding of the role of insomnia symptoms and sleep duration as risk factors for new-onset mental disorders in a large, population-based, prospective investigation of military personnel. The aim of our study was to evaluate predeployment sleep in relation to the development of PTSD, depression, and anxiety, and whether combat-related trauma modified these associations.

METHODS

Study Population and Data Sources

In mid-2001, over 200,000 military personnel on active service rosters were contacted to participate in the first panel of the Millennium Cohort; 77,047 (36.0%) were enrolled. Of these, 55,021 (71%) completed a first follow-up questionnaire (2004-2006), 54,790 (71%) completed a second follow-up (2007-2008), and 46,438 (60%) completed both follow-ups. Another

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31,110 (25%) were enrolled in a second panel (2004-2006). Of these individuals, 17,152 (55%) completed a first follow-up survey (2007-2008). Additional details regarding Millennium Cohort methodology have been published elsewhere.²⁰⁻²²

In order to prospectively examine risk factors for postdeployment new-onset mental health disorders, eligibility criteria for this study included: having at least one deployment between their baseline and a follow-up questionnaire; having no deployments before their baseline questionnaire; screening negative for PTSD, depression, anxiety, or panic predeployment; and no indication of a prior diagnosis of a mental disorder or use of psychotropic medications predeployment. For the depression model, an additional eligibility criterion was that women must not have reported being pregnant or recently giving birth on their predeployment assessment to avoid instances of postpartum depression. Based on these criteria to execute the study design, 18,175 Millennium Cohort participants were eligible for these analyses. After removing those missing outcome ($n = 1,196$), exposure ($n = 240$), or covariate data ($n = 1,535$), our final study population was 15,204 for PTSD and anxiety models, and 15,000 for the depression model.

This study population, comprised only of deployers, was grouped based on the timing of their first deployment. The early deployment group (Group 1, $n = 9,043$) included Panel 1 members who had their first deployment between the first (2001-2003) and second (2004-2006) survey cycles. The later deployment group (Group 2, $n = 6,161$) were Panel 1 and Panel 2 participants who had their first deployment between the second (2004-2006) and third (2007-2008) survey cycles.

Military-specific data, including deployment dates, deployment location, service branch, pay grade, occupation, service component, and demographics, were provided by the Defense Manpower Data Center (see Table 1). Millennium Cohort questionnaire data were used to assess all other covariates. Current smokers were defined as those who indicated smoking > 100 cigarettes in their lifetime and had not tried or were unsuccessful at quitting. The 4-item CAGE (Cut-back, Annoy, Guilty, Eye-opener) questionnaire was used to assess potential problem drinkers, where individuals who positively endorsed ≥ 1 item were defined as having potential alcohol problems.²³ History of life stressors was determined using scoring mechanisms adapted from the Holmes and Rahe Social Readjustment Rating Scale.²⁴

Predeployment sleep was assessed in 2 ways: insomnia symptoms and sleep duration. Average sleep duration (in a 24-h period) during the past month was self-reported in whole number hourly increments. Insomnia symptoms were assessed using questions from the Patient Health Questionnaire (PHQ)^{25,26} for anxiety and the PTSD Checklist, Civilian Version (PCL-C).²⁷ Insomnia symptoms were defined as responding “moderately” or above in response to the question “In the past month, have you had trouble falling asleep or staying asleep?” on the PCL-C; or responding “several days” or longer to the question “Over the last 4 weeks, how often have you experienced trouble falling asleep or staying asleep?” on the PHQ.

Combat-related traumas were defined as having personally (1) witnessed a death due to war, disaster, or tragic event; (2) witnessed instances of physical abuse; (3) been exposed to dead or decomposing bodies; (4) been exposed to maimed soldiers or civilians; or (5) been exposed to prisoners of war or refugees.

These were evaluated at follow-up as having occurred during the same time period as deployment. All covariates, except combat-related trauma, were assessed at the predeployment survey.

Outcomes

New-onset PTSD was assessed using the 17-item PCL-C.^{27,28} A participant screened positive according to *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) criteria when ≥ 3 avoidance symptoms, 2 hyperarousal symptoms, and 1 intrusion symptom were endorsed at “moderate” or higher levels.^{27,29} Since the sleep item from the PCL-C was used to define insomnia symptoms, PTSD was scored without this item.

New-onset depression was assessed using the PHQ-9, a validated screening instrument based on DSM-IV diagnostic criteria.^{25,30-32} Participants screened positive if they responded “more than half the days” or “nearly every day” to ≥ 5 of the 9 depressive symptoms, and 1 of the 5 items endorsed was depressed mood or anhedonia.²⁵

New onset of generalized anxiety disorder was assessed using the 7-item anxiety module in the PHQ, which is composed of generalized anxiety disorder symptoms excluding anxiety related to panic attacks or exclusively in relation to PTSD. Persons screened positive if they indicated feeling nervous, anxious, on edge; or worrying a lot on more than half the days over the past 4 weeks and they indicated experiencing ≥ 3 of the 6 other anxiety symptoms on more than half the days. The sleep item in the anxiety module was used to create the insomnia symptoms variable, so the anxiety outcome was scored without this item.

Statistical Analyses

Chi-square tests of association and univariate logistic regression models were used to assess unadjusted relationships between each mental disorder and all covariates. Multivariable logistic regression models were used to determine the odds of new-onset PTSD, depression, and anxiety postdeployment, in relation to predeployment sleep duration and insomnia symptoms, after adjusting for relevant demographic, military, and health covariates. All covariates were included in models based on published literature. Race/ethnicity was included because previous research has shown that ethnic minority veterans have higher rates of mental illness than Caucasian veterans.^{33,34} Regression diagnostics were used to assess multicollinearity between all covariates.

In multivariable analyses, interactions were tested to examine whether combat-related trauma modified the relationship between insomnia symptoms and each mental health outcome, with the criterion for significance being $\alpha = 0.10$, 2-sided. In addition, 2 sensitivity analyses were performed. The first included additional deployment-related exposures (deployment location, percent time deployed, multiple deployments, and dwell time). Dwell time is a ratio of the time spent at home between 2 deployments to the time spent on the preceding deployment. The second sensitivity analysis tested the combat variable to ensure that 1 of the items, “witnessed instance of physical abuse,” was not driving a spurious association. The 5 items used to identify combat-related trauma were evaluated at follow-up and asked about experiences over the last 3 years, which corresponded to the same time period as a deployment. However, participants were not specifically asked if these events occurred while de-

ployed, and the physical abuse item has the most potential to be unrelated to deployment. Therefore, we conducted sensitivity analyses where combat-related trauma was reevaluated excluding the abuse item. In addition, to explore mental health outcomes for the most severe phenotype of insomnia symptoms with short sleep duration, a secondary analysis was run to examine those who reported insomnia symptoms and the shortest nightly sleep duration (< 6 h). The sleep exposure variables were combined and categorized into 4 groups: (1) insomnia symptoms and < 6 h sleep per night, (2) insomnia symptoms and \geq 6 h sleep per night, (3) no insomnia symptoms and < 6 h of sleep per night, (4) no insomnia symptoms and \geq 6 hours of sleep per night (reference).

This study was approved by the Naval Health Research Center Institutional Review Board, and informed consent was obtained from all subjects. Data management and statistical analyses were performed using SAS statistical software, version 9.3 (SAS Institute, Inc., Cary, North Carolina).

RESULTS

At follow-up, 522 people screened positive for new-onset PTSD, 151 for anxiety, and 303 for depression. Approximately 50% of subjects reported combat-related trauma, and 17% reported insomnia symptoms predeployment (Table 1). Mean predeployment sleep duration was similar for Group 1 and Group 2—6.7 and 6.6 h, respectively. Compared with Group 2, Group 1 subjects, who deployed earlier, were more likely to be older, male, less educated, married, in the Air Force, serving on active duty, combat specialists, enlisted, overweight, and to report greater life stress, current smoking, and problem drinking.

PTSD

The association between predeployment sleep duration and postdeployment new-onset PTSD was modified by the Group variable ($P = 0.02$), so all analyses were stratified by deployment group. For both Groups, those who slept < 6 h predeployment had significantly greater odds of developing PTSD than those who slept 7 hours (Table 2). Among Group 1 and Group 2, those who reported insomnia symptoms prior to deployment had increased odds (odds ratio [OR], 2.37; 95% confidence interval [CI], 1.78-3.15, and OR, 1.80; 95% CI, 1.32-2.45, respectively) of developing PTSD. Among Group 2, those who slept > 8 h had increased odds of developing PTSD following deployment, as did those with insomnia symptoms. Participants who reported combat-related trauma had over 2 times the odds of developing PTSD in both groups. Additional factors associated with increased odds of new onset PTSD among both groups included being in the Army compared with the Air Force, being in the Reserve/Guard, and reporting higher stress and current smoking. There was no significant interaction between combat-related trauma and insomnia symptoms. Among Group 1 and Group 2, those with the most severe phenotype (insomnia symptoms and short sleep [< 6 h per night]) had significantly increased odds of developing PTSD following deployment (OR: 3.00, 95% CI: 2.05-4.38, and OR: 2.46 95% CI: 1.65-3.68, respectively).

Depression

Combat significantly modified the association between depression and insomnia symptoms (Group 1, $P < 0.01$; Group 2,

$P = 0.04$), so the odds of depression in relation to insomnia symptoms are presented separately for persons with and without combat-related trauma. For Group 1, the adjusted odds of developing depression were highest in those with both insomnia symptoms and combat (OR, 5.98; 95% CI, 3.15-11.35), followed by insomnia symptoms only, then combat only (Table 3). The same pattern and similar strength of association was seen in Group 2. Differences in sleep duration were not significant. Among Group 1, women, individuals in the Army and Marines, those with lower general health, and those considered obese, had significantly increased odds of developing depression. Among Group 2, younger, single participants, those with high stress, and current smokers had increased odds of developing depression. Secondary analyses assessing those who reported insomnia symptoms and short sleep duration were not performed for the depression model due to the interaction between combat and insomnia symptoms.

Anxiety

Among Group 1 participants, those who slept < 6 h per day and those with insomnia symptoms had increased odds of developing anxiety postdeployment (Table 4). Among Group 2, sleep duration was not significant, but those who reported insomnia symptoms or combat-related trauma had significantly increased odds, which were the only significant variables for this Group. Group 1 showed that those with lower general health and higher stress had increased odds for anxiety. There was no significant interaction between combat-related trauma and insomnia symptoms in relation to new-onset anxiety. Among Group 1 and Group 2, those with insomnia symptoms and < 6 h sleep per night had significantly increased odds of developing anxiety following deployment compared to those who did not have insomnia symptoms and slept ≥ 6 h per night (Group 1 OR: 4.33, 95% CI: 2.37-7.90, and Group 2 OR: 4.14 95% CI: 2.09-8.22).

Insomnia Symptoms

Since this study used one sleep item from the PHQ and one sleep item from the PCL to evaluate insomnia symptoms, and this is not a validated measure of sleep, we assessed the overlap between the 2 sleep items. Results indicated notable overlap among those who met the criteria for insomnia symptoms: 30% met the criteria on both scales, 50% met the criteria on the PHQ only (a more sensitive measure), and 20% met the criteria on the PCL only (a more specific measure). To further examine whether or not using the 2 items combined created a more sensitive measure for insomnia symptoms, we ran new models defining insomnia symptoms based on each sleep item separately and compared these results to those from our original models. Findings showed that the point estimates decreased when the PCL sleep item was used and increased when the PHQ sleep item was used. However, for both the PCL and PHQ sleep models, the point estimates were within the 95% CI of the original models.

Sensitivity Analyses

Sensitivity analyses comparing the main models to models with additional deployment variables showed consistent results and did not reveal any additional factors that contribute to mental disorders. The strength and direction of the associa-

Table 1—Demographic, military and behavioral characteristics of 15,204 Millennium Cohort participants by timing of first deployment

Characteristics ^c	Group1 ^a N = 9,043 n (%)	Group2 ^b N = 6,161 n (%)	P Value	Characteristics ^c	Group1 ^a N = 9,043 n (%)	Group2 ^b N = 6,161 n (%)	P Value
New-onset PTSD	270 (3.0)	252 (4.1)	< 0.01	Service branch			< 0.01
New-onset anxiety	88 (1.0)	63 (1.0)	0.76	Army	4,195 (46.4)	3,170 (51.5)	
New-onset depression	150 (1.7)	153 (2.5)	< 0.01	Air Force	3,231 (35.7)	1,698 (27.5)	
Sleep duration, h			0.55	Navy and Coast Guard	1,162 (12.9)	1,000 (16.2)	
< 6	1,294 (14.3)	904 (14.7)		Marine Corps	455 (5.0)	293 (4.8)	
6	2,990 (33.1)	2,091 (33.9)		Service component			< 0.01
7	2,723 (30.1)	1,825 (29.6)		Reserve/National Guard	3,497 (38.7)	3,054 (49.6)	
8	1,600 (17.7)	1,038 (16.9)		Active duty	5,546 (61.3)	3,107 (50.4)	
> 8	436 (4.8)	303 (4.9)		Occupation			< 0.01
Continuous hours (mean ± SD)	6.7 ± 1.3	6.6 ± 1.3		Combat specialists	2,294 (25.4)	1,198 (19.4)	
Insomnia symptoms			0.58	Health care	631 (7.0)	603 (9.8)	
No	7,515 (83.1)	5,099 (82.8)		Admin/supply	2,188 (24.2)	1,732 (28.1)	
Yes	1,528 (16.9)	1,062 (17.2)		Other	3,930 (43.5)	2,628 (42.7)	
Combat ^d			0.78	Pay grade			< 0.01
No	4,512 (49.9)	3,088 (50.1)		Enlisted	6,543 (72.4)	4,255 (69.1)	
Yes	4,531 (50.1)	3,073 (49.9)		Officer	2,500 (27.6)	1,906 (30.9)	
Birth year			< 0.01	Self-rated general health			0.12
Pre-1960	1,571 (17.4)	583 (9.5)		Fair/poor	373 (4.1)	217 (3.5)	
1960-1969	3,759 (41.6)	1,981 (32.1)		Good	2,521 (27.9)	1,768 (28.7)	
1970-1979	3,235 (35.8)	2,070 (33.6)		Very good/excellent	6,149 (68.0)	4,176 (67.8)	
1980 and later	478 (5.3)	1,527 (24.8)		Body mass index (BMI)			< 0.01
Continuous age (mean ± SD)	33.1 ± 8.3	32.3 ± 9.2		Underweight/healthy weight	3,230 (35.7)	2,415 (39.2)	
Sex			< 0.01	Overweight	4,994 (55.2)	3,124 (50.7)	
Male	7,519 (83.1)	4,606 (74.8)		Obese	819 (9.1)	622 (10.1)	
Female	1,524 (16.9)	1,555 (25.2)		Continuous BMI (mean ± SD)	25.9 ± 3.1	25.9 ± 3.3	
Race/ethnicity			0.92	Life stressors ^e			< 0.01
White, non-Hispanic	6,380 (70.6)	4,331 (70.3)		Low/mild	8,077 (89.3)	5,974 (97.0)	
Black, non-Hispanic	958 (10.6)	664 (10.8)		Moderate/major	966 (10.7)	187 (3.0)	
Other	1,705 (18.8)	1,166 (18.9)		Smoking status			< 0.01
Highest educational level			< 0.01	Past/never	7,541 (83.4)	5,272 (85.6)	
Some college or less	6,476 (71.6)	4,103 (66.6)		Current	1,502 (16.6)	889 (14.4)	
Bachelor's degree or higher	2,567 (28.4)	2,058 (33.4)		Problem drinker/CAGE			< 0.01
Marital status			< 0.01	No	7,409 (81.9)	5,192 (84.3)	
Single	2,569 (28.4)	2,232 (36.2)		Yes	1,634 (18.1)	969 (15.7)	
Married	5,934 (65.6)	3,632 (59.0)					
Divorced/widowed/ separated	540 (6.0)	297 (4.8)					

^aGroup1 includes personnel who completed their first deployment between the 2001 and 2004 survey cycles. ^bGroup 2 includes personnel who completed their first deployment between the 2004 and 2007 survey cycles. ^cAll variables assessed predeployment, except for combat and new-onset PTSD, depression, and anxiety. ^dCombat was defined as self-report of having personally experienced combat or combat-like situation such as witnessing a person's death due to war, disaster, or tragic event, and was evaluated at follow-up as having occurred during the same time period as deployment. ^eHistory of life stress was assessed by applying scoring mechanisms from the Holmes and Rahe Social Readjustment Rating Scale. Gray highlighted area indicates mean ± SD for characteristics immediately above.

tions between predeployment sleep and postdeployment mental disorders remained stable after the addition of deployment location, number of deployments, percent time deployed, and dwell time (data not shown). Sensitivity analyses comparing the results of the main models using the 5-item combat definition to the 4-item combat definition also showed no significant differences (data not shown).

DISCUSSION

Understanding environmental and behavioral risk factors associated with the onset of common major mental disorders is of great importance in a military occupational setting. This study is the first prospective investigation of the relationship between sleep disturbance and development of newly identified positive screens for mental disorders in a large military cohort who have

Table 2—Adjusted odds of new-onset PTSD following deployment in 15,204 Millennium Cohort participants (2001-2008)

Characteristics ^c	Group1 ^a N = 9,043 OR (95% CI)	Group2 ^b N = 6,161 OR (95%CI)	Characteristics ^c	Group1 ^a N = 9,043 OR (95% CI)	Group2 ^b N = 6,161 OR (95%CI)
Main model^d			Service component		
Sleep duration, h			Reserve/National Guard	1.00	1.00
< 6	1.61 (1.08-2.39)	1.81 (1.18-2.77)	Active duty	0.62 (0.47-0.83)	0.69 (0.51-0.92)
6	1.16 (0.81-1.67)	1.25 (0.84-1.85)	Occupation		
7	1.00	1.00	Combat specialists	1.00	1.00
8	1.40 (0.91-2.16)	1.33 (0.83-2.13)	Health care	0.50 (0.26-0.96)	0.61 (0.36-1.04)
> 8	1.14 (0.61-2.14)	2.09 (1.18-3.69)	Admin/supply	0.87 (0.60-1.27)	0.83 (0.56-1.22)
Insomnia symptoms			Other	0.95 (0.69-1.32)	0.76 (0.53-1.08)
No	1.00	1.00	Pay grade		
Yes	2.37 (1.78-3.15)	1.80 (1.32-2.45)	Enlisted	1.00	1.00
Combat^e			Officer	0.66 (0.38-1.15)	0.49 (0.28-0.87)
No	1.00	1.00	Self-rated general health		
Yes	2.84 (2.04-3.96)	3.88 (2.76-5.46)	Very good/excellent	1.00	1.00
Birth year			Good	1.33 (1.01-1.76)	1.30 (0.97-1.74)
Pre-1960	1.00	1.00	Fair/poor	1.56 (0.96-2.54)	1.76 (1.02-3.04)
1960-1969	0.82 (0.53-1.26)	1.35 (0.74-2.46)	Body mass index		
1970-1979	1.27 (0.81-2.00)	1.37 (0.75-2.53)	Underweight/healthy weight	1.00	1.00
1980 and later	1.84 (1.00-3.39)	1.54 (0.75-3.07)	Overweight	1.02 (0.76-1.36)	1.48 (1.08-2.02)
Sex			Obese	1.22 (0.77-1.95)	1.65 (1.04-2.62)
Male	1.00	1.00	Life stressors^f		
Female	1.31 (0.92-1.86)	1.66 (1.18-2.33)	Low/mild	1.00	1.00
Race/ethnicity			Moderate/major	1.84 (1.33-2.57)	2.52 (1.55-4.08)
White, non-Hispanic	1.00	1.00	Smoking status		
Black, non-Hispanic	0.92 (0.60-1.43)	0.93 (0.59-1.48)	Past/never	1.00	1.00
Other	1.38 (0.98-1.96)	1.23 (0.86-1.76)	Current	1.57 (1.18-2.10)	1.80 (1.32-2.45)
Highest educational level			Problem drinker/CAGE		
Some college or less	1.00	1.00	No	1.00	1.00
Bachelor's degree or higher	0.79 (0.46-1.35)	0.74 (0.44-1.26)	Yes	1.21 (0.90-1.63)	1.17 (0.84-1.63)
Marital status			Secondary model^g		
Single	1.00	1.00	Short sleep duration (< 6 h) and insomnia symptoms		
Married	1.00 (0.72-1.38)	0.93 (0.65-1.33)	Neither	1.00	1.00
Divorced/widowed/separated	0.91 (0.50-1.65)	1.15 (0.61-2.14)	Short sleep only	1.78 (1.19-2.65)	1.59 (1.06-2.40)
Service branch			Insomnia symptoms only	2.73 (1.97-3.80)	1.94 (1.34-2.81)
Army	1.00	1.00	Short sleep and insomnia symptoms	3.00 (2.05-4.38)	2.46 (1.65-3.68)
Air Force	0.38 (0.26-0.57)	0.35 (0.22-0.54)			
Navy and Coast Guard	0.50 (0.29-0.86)	0.84 (0.56-1.28)			
Marine Corps	0.77 (0.43-1.36)	0.44 (0.19-1.02)			

CI, confidence interval; OR, odds ratio. ^aGroup 1 includes personnel who completed their first deployment between the 2001 and 2004 survey cycles. ^bGroup 2 includes personnel who completed their first deployment between the 2004 and 2007 survey cycles. ^cAll variables assessed predeployment, except for combat. ^dORs and associated 95% CIs are adjusted for all variables listed in the main model. ^eCombat defined as self-report of having personally experienced combat or combat-like situation such as witnessing a person's death due to war, disaster, or tragic event, and was evaluated at follow-up as having occurred during the same time period as deployment. ^fHistory of life stress was assessed by applying scoring mechanisms from the Holmes and Rahe Social Readjustment Rating Scale. ^gSecondary model assessed the potentially severe phenotype of short sleep duration and insomnia symptoms. Model adjusted for combat, birth year, sex, race/ethnicity, education, marital status, service branch, service component, occupation, pay grade, general health, BMI, life stressors, smoking status, problem drinking/CAGE. Bold type indicates statistical significance ($P < 0.05$).

been deployed in support of the recent operations in Iraq or Afghanistan. We found a statistically significant increased risk for new-onset PTSD, depression, and anxiety positive screens in those reporting predeployment insomnia symptoms independent of other potential risk factors. Additionally, short sleep duration (< 6 h) was associated with new-onset PTSD symptoms. These results are consistent with the large body of prior research that has found insomnia to be a risk factor for new-onset mental

illness, particularly depression, in non-military populations.⁷⁻¹⁹ Given the unique experiences of deployed military personnel relative to the general population, the results of this study significantly add to this body of research.

Other investigations have documented mental health symptoms among recently deployed US service members. Using the Post-Deployment Health Assessment survey, the prevalence of mental health problems among service members returning

Table 3—Adjusted^a odds of new-onset depression following deployment in 15,000 Millennium Cohort participants (2001-2008)

Characteristics ^d	Group1 ^b	Group2 ^c	Characteristics ^d	Group1 ^b	Group2 ^c
	N = 8,902	N = 6,098		N = 8,902	N = 6,098
	OR (95% CI)	OR (95%CI)		OR (95% CI)	OR (95%CI)
Sleep duration, h			Service branch		
< 6	1.66 (1.00-2.74)	1.42 (0.82-2.45)	Army and Marines	1.00	1.00
6	0.90 (0.55-1.47)	1.25 (0.77-2.04)	Air Force	0.49 (0.30-0.79)	0.36 (0.21-0.63)
7	1.00	1.00	Navy and Coast Guard	0.39 (0.18-0.83)	0.63 (0.36-1.10)
8	1.54 (0.90-2.66)	1.60 (0.91-2.82)	Service component		
> 8	0.95 (0.41-2.24)	1.99 (0.97-4.10)	Reserve/National Guard	1.00	1.00
Combat and insomnia symptoms ^e			Active duty	0.90 (0.61-1.31)	0.81 (0.57-1.17)
Neither	1.00	1.00	Occupation		
Combat only	3.86 (2.19-6.81)	3.01 (1.83-4.94)	Combat specialists	1.00	1.00
Insomnia symptoms only	4.43 (2.19-8.95)	3.83 (2.01-7.31)	Health care	0.71 (0.32-1.60)	0.89 (0.47-1.71)
Combat and insomnia symptoms	5.98 (3.15-11.35)	5.34 (2.99-9.52)	Admin/supply	1.03 (0.62-1.71)	0.89 (0.55-1.44)
Other			Other	1.07 (0.69-1.68)	0.74 (0.47-1.18)
Birth year			Pay grade		
Pre-1960	1.00	1.00	Enlisted	1.00	1.00
1960-1969	0.85 (0.48-1.52)	1.89 (0.84-4.28)	Officer	0.64 (0.30-1.37)	0.50 (0.24-1.03)
1970-1979	1.13 (0.62-2.07)	1.58 (0.69-3.64)	Self-rated general health		
1980 and later	1.58 (0.71-3.52)	2.90 (1.16-7.25)	Very good/excellent	1.00	1.00
Sex			Good	1.71 (1.19-2.47)	1.14 (0.79-1.66)
Male	1.00	1.00	Fair/poor	2.15 (1.17-3.88)	1.74 (0.90-3.36)
Female	1.91 (1.23-2.96)	1.29 (0.84-1.98)	Body mass index		
Race/ethnicity			Underweight/healthy weight	1.00	1.00
White, non-Hispanic	1.00	1.00	Overweight	0.85 (0.58-1.24)	0.87 (0.59-1.26)
Black, non-Hispanic	0.91 (0.53-1.55)	1.21 (0.71-2.07)	Obese	1.79 (1.05-3.07)	1.21 (0.69-2.11)
Other	1.14 (0.71-1.83)	1.25 (0.80-1.94)	Life stressors ^f		
Highest educational level			Low/mild	1.00	1.00
Some college or less	1.00	1.00	Moderate/major	1.39 (0.88-2.19)	2.22 (1.22-4.03)
Bachelor's degree or higher	0.87 (0.42-1.78)	0.82 (0.42-1.61)	Smoking status		
Marital status			Past/never	1.00	1.00
Single	1.00	1.00	Current	1.32 (0.90-1.95)	1.60 (1.08-2.36)
Married	0.86 (0.56-1.31)	1.71 (1.08-2.72)	Problem drinker/CAGE		
Divorced/widowed/separated	0.69 (0.30-1.56)	2.37 (1.13-4.99)	No	1.00	1.00
			Yes	1.02 (0.67-1.54)	1.20 (0.79-1.81)

CI, confidence interval; OR, odds ratio. ^aORs and associated 95% CIs are adjusted for all variables listed in the table. ^bGroup1 includes participants who completed their first deployment between the 2001 and 2004 survey cycles. ^cGroup 2 includes participants who completed their first deployment between the 2004 and 2007 survey cycles. ^dAll variables assessed predeployment, except for combat. ^eCombat defined as self-report of having personally experienced combat or combat-like situation such as witnessing a person's death due to war, disaster, or tragic event, and was evaluated at follow-up as having occurred during the same time period as deployment. ^fHistory of life stress was assessed by applying scoring mechanisms from the Holmes and Rahe Social Readjustment Rating Scale. Bold type indicates statistical significance ($P < 0.05$).

from Iraq and Afghanistan was 20.3%¹ and 19.1%³⁵ (42.4% in Reservists).¹ In contrast, our study captured new-onset cases, thereby excluding those who screened positive predeployment for PTSD, depression, and anxiety, which might explain why our postdeployment rates were lower than in past studies. Our prospective results are consistent with previous findings of an increased risk of mental disorders following exposures to combat,³⁶⁻³⁸ but they are the first to show that insomnia symptoms may confer further susceptibility among military personnel. However, by early identification of those most vulnerable, the potential exists for the designing and testing of preventive strategies that may reduce the occurrence of PTSD, anxiety, and depression.

One of the more interesting findings of this study is not only the degree of risk conferred by predeployment insomnia symp-

toms, but also the relative magnitude of this risk compared with combat-related trauma. The risk conferred by insomnia symptoms was almost as strong as our measure of combat exposure in adjusted models. There is evidence demonstrating a temporal relationship between insomnia symptoms and the future development of mental disorders, but empirically based explanations for these relationships are limited.^{6,39-46} The mechanisms linking insomnia symptoms and mental health may involve processes related to specific sleep stages. REM sleep mechanisms are one potential candidate, given that REM fragmentation has been proposed in the development of PTSD.^{41,47} Alternatively, cognitive mechanisms may be implicated, such as those involved in rumination/worry or coping. Future research should investigate the causal pathways linking insomnia symptoms and new-onset mental health disorders.⁴⁸

Table 4—Adjusted odds of new-onset anxiety following deployment in 15,204 Millennium Cohort participants (2001-2008)

Characteristics ^c	Group1 ^a	Group2 ^b	Characteristics ^c	Group1 ^a	Group2 ^b
	N = 9,043	N = 6,161		N = 9,043	N = 6,161
	OR (95% CI)	OR (95%CI)		OR (95% CI)	OR (95%CI)
Main model^d					
Sleep duration, h			Service component		
< 6	2.42 (1.21-4.85)	1.25 (0.56-2.80)	Reserve/National Guard	1.00	1.00
6	1.40 (0.71-2.74)	1.02 (0.49-2.14)	Active duty	0.74 (0.45-1.21)	0.85 (0.48-1.48)
7	1.00	1.00	Occupation		
≥ 8	1.45 (0.68-3.08)	1.44 (0.65-3.19)	Combat specialists	1.00	1.00
Insomnia symptoms			Health care	0.62 (0.23-1.69)	1.01 (0.40-2.55)
No	1.00	1.00	Admin/supply	0.60 (0.31-1.16)	0.99 (0.46-2.09)
Yes	2.42 (1.51-3.89)	3.37 (1.93-5.90)	Other	0.85 (0.50-1.46)	0.77 (0.37-1.60)
Combat ^e			Pay grade		
No	1.00	1.00	Enlisted	1.00	1.00
Yes	1.67 (1.00-2.79)	5.64 (2.74-11.61)	Officer	2.01 (0.84-4.81)	0.69 (0.23-2.07)
Birth year			Self-rated general health		
Pre-1970	1.00	1.00	Very good/excellent	1.00	1.00
1970-1979	1.54 (0.91-2.60)	1.39 (0.73-2.65)	Good	1.91 (1.18-3.09)	0.83 (0.46-1.51)
1980 and later	1.61 (0.66-3.95)	2.26 (0.96-5.32)	Fair/poor	2.81 (1.35-5.85)	1.66 (0.63-4.37)
Sex			Body mass index		
Male	1.00	1.00	Underweight/healthy weight	1.00	1.00
Female	1.13 (0.63-2.03)	1.69 (0.90-3.18)	Overweight	0.86 (0.53-1.41)	0.84 (0.47-1.51)
Race/ethnicity			Obese	1.17 (0.55-2.50)	1.79 (0.80-4.00)
White, non-Hispanic	1.00	1.00	Life stressors ^f		
Black, non-Hispanic	1.06 (0.51-2.17)	1.30 (0.58-2.93)	Low/mild	1.00	1.00
Other	1.14 (0.62-2.08)	1.19 (0.59-2.39)	Moderate/major	2.43 (1.43-4.13)	1.36 (0.51-3.65)
Highest educational level			Smoking status		
Some college or less	1.00	1.00	Past/never	1.00	1.00
Bachelor's degree or higher	0.44 (0.17-1.09)	0.73 (0.25-2.11)	Current	1.26 (0.76-2.09)	1.43 (0.77-2.65)
Marital status			Problem drinker/CAGE		
Single	1.00	1.00	No	1.00	1.00
Married	0.66 (0.39-1.13)	1.80 (0.90-3.61)	Yes	0.95 (0.57-1.61)	0.91 (0.46-1.81)
Divorced/widowed/ separated	0.75 (0.29-1.97)	2.52 (0.82-7.79)	Secondary Model^g		
Service branch			Short sleep duration (< 6 h) and insomnia symptoms		
Army and Marine Corps	1.00	1.00	Neither	1.00	1.00
Air Force	0.62 (0.33-1.16)	0.92 (0.47-1.82)	Short sleep only	2.41 (1.25-4.67)	0.61 (0.18-2.02)
Navy and Coast Guard	0.80 (0.38-1.72)	1.02 (0.44-2.37)	Insomnia symptoms only	2.95 (1.66-5.24)	2.62 (1.36-5.07)
			Short sleep and insomnia symptoms	4.33 (2.37-7.90)	4.14 (2.09-8.22)

CI, confidence interval; OR, odds ratio. ^aGroup1 includes personnel who completed their first deployment between the 2001 and 2004 survey cycles. ^bGroup 2 includes personnel who completed their first deployment between the 2004 and 2007 survey cycles. ^cAll variables assessed predeployment, except for combat. ^dORs and associated 95% CIs are adjusted for all variables listed in the main model. ^eCombat defined as self-report of having personally experienced combat or combat-like situation such as witnessing a person's death due to war, disaster, or tragic event, and was evaluated at follow-up as having occurred during the same time period as deployment. ^fHistory of life stress was assessed by applying scoring mechanisms from the Holmes and Rahe Social Readjustment Rating Scale. ^gSecondary model assessed the potentially severe phenotype of short sleep duration and insomnia symptoms. Model adjusted for combat, birth year, sex, race/ethnicity, education, marital status, service branch, service component, occupation, pay grade, general health, BMI, life stressors, smoking status, problem drinking/CAGE. Bold type indicates statistical significance ($P < 0.05$).

A consistent theme of these findings is the association between insomnia symptoms and newly screening positive for mental disorders. Less consistent is the association between perceived sleep duration, with shorter and longer sleep duration associated with higher odds of PTSD, shorter sleep duration only for anxiety, and neither for depression. Insomnia symptoms as opposed to perceived sleep quantity, therefore, emerge from these results as a more consistent predictor of mental health outcomes. This is consistent with a study among girls at higher risk for depression who reported in-

somnia symptoms but not short sleep duration.⁴⁹ It may be that short sleep would be a more significant risk factor in those with higher sleep need, but there are currently no clear means of assessing individual sleep requirements that would allow these patterns to be further explored. There is also a growing body of literature assessing health outcomes among those with insomnia and short sleep duration that has demonstrated this group is at increased risk for hypertension,⁵⁰⁻⁵³ type 2 diabetes,⁵⁴ mental illness,^{55,56} and mortality.^{57,58} Findings from this study support and add to the previous litera-

ture, suggesting that this unique group may need additional research and interventions.

The relationship between combat-related trauma and mental disorders has been documented in other studies from this cohort.^{2,3,59} Insomnia symptoms have also been shown to be a risk factor for depression,⁷⁻¹⁹ as was confirmed in this study. Although we hypothesized that insomnia symptoms would modify the relationship between combat and new-onset mental disorders, this effect modification was only statistically significant for depression. Furthermore, the interaction was opposite the expected direction, with the odds of depression associated with insomnia symptoms and combat-related trauma lower than would have been expected from the multiplicative product of the odds ratio for each exposure measured separately. Thus, insomnia symptoms prior to deployment did not amplify the elevation in risk of postdeployment depression associated with combat-related trauma. Perhaps there is a unique biological aspect to the development of depression versus the development of PTSD, which appears to have a stronger, independent association with combat-related trauma regardless of insomnia symptoms.

This study had several limitations that must be noted. The variable “insomnia symptoms” was created using the sleep items found on the PCL-C and the anxiety scale on the PHQ. While the PHQ and PCL-C are validated instruments, those specific sleep items have not been validated for use as a measure of insomnia symptoms. Also, our measure of combat exposure is based on witnessing or being exposed to combat-related trauma, but is not a direct measure of active engagement in combat, so it is not clear if it is combat per se that was associated with an increased risk of new-onset mental illness. In addition, 84% of our eligible study population had complete data for final models. However, among those removed from the analyses due to missing outcome data, approximately 15% reported insomnia symptoms and the mean sleep duration was 6.7 hours; this was very similar to the prevalence of insomnia symptoms (17%) and mean sleep duration (6.6-6.7 h) of those included in analyses. Since we are unable to ascertain whether these individuals developed a mental disorder following deployment, these missing data may have biased our results in either direction. However, an examination of nonresponse bias in the Millennium Cohort has shown that prospective analyses are not substantially biased by nonresponse.⁶⁰ Self-reported data may be subject to recall bias and may not represent the true prevalence of a characteristic, although investigation of this cohort suggests that participant data are reliable for health and military data (e.g., vaccinations and occupations).⁶¹⁻⁶⁴ Furthermore, since the burden of mental disorders may be underrepresented in medical record data because not all individuals seek care, screening tools on confidential surveys may have captured a greater burden of disease. Finally, overestimations of nightly sleep duration have been reported in normal sleepers,^{65,66} while those with insomnia tend to underestimate their actual sleep duration.⁶⁷

Despite these limitations, this study had many strengths. The exposure of interest, sleep disturbance, was measured in 2 ways: sleep duration and insomnia symptoms. The study included participants from all branches and components of the service, and our population was stratified by timing of first deployment, which accounted for issues like operational tempo, for which we could not otherwise control. The study had a large sample

size and information on many covariates, allowing us to control for potential confounders, including important deployment-related characteristics. In addition, this study was longitudinal in design, with two consecutive surveys for all participants.

Temporal patterns of the relationship between insomnia symptoms, traumatic exposures, and the development of mental disorders among military suggest a potential role for predeployment screening to identify persons at higher risk for postdeployment mental disorders. Insomnia symptoms could be a marker of vulnerability to mental disorders, an early manifestation of illness, or represent reduced capacity for emotional or physical resources to deal with stressors, thus hindering recovery from posttraumatic stress reactions.^{5,6,13} Notably, resolution of sleep disorders has previously been associated with reduced incidence of psychiatric disorders.¹³ Future studies are needed to investigate whether routine inquiry of insomnia symptoms and application of appropriate early, effective interventions reduces subsequent morbidity from mental disorders. In a military population, assessment of insomnia symptoms could be incorporated into routine predeployment screening. Insomnia symptoms are important predictors of future mental health, and both sleep quality and quantity should be considered as indicative of future vulnerability to mental disorders.

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