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ORIGINAL ARTICLE

Pre-deployment insomnia is associated with post-deployment post-traumatic stress disorder and suicidal ideation in US Army soldiers

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Abstract

Study Objectives: Insomnia is prevalent among military personnel and may increase risk of mental disorders and suicidal ideation. This study examined associations of pre-deployment insomnia with post-deployment post-traumatic stress disorder (PTSD) and suicidal ideation among US Army soldiers.

Methods: Soldiers from three Brigade Combat Teams completed surveys 1–2 months before deploying to Afghanistan in 2012 (T0), on return from deployment (T1), 3 months later (T2), and 9 months later (T3). Logistic regression was performed to estimate associations of pre-deployment (T0) insomnia with post-deployment (T2 or T3) PTSD and suicidal ideation among respondents who completed surveys at all waves (n = 4645). A hierarchy of models incorporated, increasing controls for pre-deployment risk factors and deployment experiences.

Results: Pre-deployment insomnia was associated with increased risk of post-deployment PTSD (adjusted odds ratio [AOR] = 3.14, 95% confidence interval [CI] = 2.58% to 3.82%, $p < .0005$) and suicidal ideation (AOR = 2.78, 95% CI = 2.07% to 3.74%, $p < .0005$) in models adjusting for sociodemographic characteristics and prior deployment history. Adjustment for other pre-deployment risk factors and deployment experiences attenuated these associations; however, insomnia remained significantly associated with post-deployment PTSD (AOR = 1.50, 95% CI = 1.19% to 1.89%, $p = .001$) and suicidal ideation (AOR = 1.43, 95% CI = 1.04% to 1.95%, $p = .027$). Subgroup models showed that pre-deployment insomnia was associated with incident PTSD (AOR = 1.55, 95% CI = 1.17% to 2.07%, $p = .003$) and suicidal ideation (AOR = 1.67, 95% CI = 1.16% to 2.40%, $p = .006$) among soldiers with no pre-deployment history of these problems.

Conclusions: Pre-deployment insomnia contributed to prediction of post-deployment PTSD and suicidal ideation in Army soldiers, suggesting that detection of insomnia could facilitate targeting of risk mitigation programs. Future studies should investigate whether treatment of insomnia helps prevent PTSD and suicidal ideation among deployed service members.

Statement of Significance

This study examines associations of baseline insomnia with onset of post-traumatic stress disorder (PTSD) and suicidal ideation following combat deployment. Prevention of mental disorders and suicidal ideation of military personnel is crucial given their significant impact on health and performance. Few large-scale prospective studies have evaluated associations of insomnia with post-deployment mental health, and of those, none have considered the outcome of suicidal ideation. We report that pre-deployment insomnia contributes to prediction of both PTSD and suicidal ideation following return from deployment. Importantly, sleep problems bring service members into treatment, which may yield opportunities for earlier intervention for mental health problems associated with greater stigma. Further research is needed to determine if treatment of insomnia would decrease incidence of PTSD and suicidal thoughts following combat deployment.

Key words: insomnia; sleep disturbance; suicide; PTSD; military personnel; deployment; stress

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Introduction

Insomnia is experienced by up to one-third of individuals in the general population [1].The relationship between insomnia and mental disorders is complex, with insomnia at times conceptualized as a prodrome or target symptom of mental disorders [2]. Evidence suggests that insomnia not only co-occurs with mental disorders, but may be an independent risk factor for developing major depression, post-traumatic stress disorder (PTSD), anxiety disorders, suicidal behaviors, and substance use disorders [3–8].

Clarifying the relationship between insomnia and mental disorders is relevant to the health and well-being of military personnel, particularly in the context of deployment, which may affect both mental health and sleep patterns [9–11]. Disruptions to the latter can affect mental and physical stamina, cognitive functioning, and operational readiness of troops [12]. Prevalence of insomnia among service members has risen in recent decades—likely due to international deployment, dramatic tempo, and higher injury risk from more destructive weaponry [10, 12, 13]—and sleep disturbance is a leading physical complaint among personnel serving in Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn, reported by 24% of noninjured soldiers and by substantially larger proportions of soldiers who had deployment-related injuries (e.g. 54% of those who sustained injuries with loss of consciousness) [14]. Importantly, sleep problems bring service members into mental health treatment and are positively associated with treatment engagement [15], which may yield opportunities for early intervention and prevention of other conditions associated with greater stigma.

This study considers pre-deployment insomnia in relation to risk of post-deployment PTSD and suicidal ideation, two conditions with established links to sleep problems and substantial impacts on military mental health [16–18]. PTSD is associated with various sleep disturbances including trauma-related nightmares, global sleep problems, sleep quality reductions, and more frequent awakenings [19]. Conversely, disturbed sleep may increase vulnerability to PTSD. Preexisting sleep problems are associated with higher likelihood of developing PTSD following traumatic events [20, 21] and combat deployment [22]. Some studies find evidence of positive feedback between sleep disturbances and PTSD symptoms, which may propel a pathological spiral that maintains and exacerbates both conditions [23]. Treatments targeting sleep disturbance also have been found to reduce PTSD symptoms [21, 24].

Suicide is one of the leading causes of death in both the general population and the US military, and identification of modifiable risk factors for suicide and nonfatal suicidal behaviors is a priority for the Armed Forces [16, 25]. Multiple studies have examined the relationship between insomnia and suicidal ideation in military populations and suggest the importance of sleep to maintain the health of military personnel [15, 26–28]; however, no prospective study has evaluated insomnia as a risk factor for onset of suicidal ideation in service members.

The Pre/Post Deployment Study (PPDS) is a longitudinal component of the Army Study to Assess Risk and Resilience in Servicemembers (Army STARRS) [29]. Its prospective design enables estimation of associations between pre-deployment insomnia and post-deployment mental health outcomes. Prior evidence suggests that insomnia disorder will be associated with increased risk of PTSD [22] and suicidal ideation [26, 30]. Although this study replicates and extends prior work related to pre-deployment insomnia and post-deployment PTSD [22, 31], to the best of our knowledge it represents the first prospective study to assess associations of pre-deployment insomnia with suicidal ideation following combat deployment.

Methods

Overview of the Pre/Post Deployment Study

The design and procedures of Army STARRS are described in detail in separate published articles [29, 32]. The PPDS surveyed US Army soldiers in three Brigade Combat Teams (BCTs). Baseline (T0) data were collected via self-administered questionnaire during the first quarter of 2012, 1–2 months before deployment of the BCTs to Afghanistan. Follow-up self-administered questionnaires were administered approximately 1 (T1), 3 (T2), and 9 months (T3) after return from deployment. The T0, T1, and T2 survey data collections were group administrations conducted at the BCTs' home posts. All soldiers currently assigned to a participating BCT were asked to report to the data collection site, receive the informed consent briefing from the Army STARRS facilitators, and then privately decide whether to consent to participation in the self-administered questionnaire. The T3 survey was an individually administered multimode survey conducted via web or telephone that was remotely managed by the Army STARRS data collection team. All PPDS respondents provided written informed consent to participate in each self-administered questionnaire. Consent also was requested to link soldiers' survey responses to their Army/Department of Defense (DoD) administrative records. Study procedures were approved by the human subjects committees of all collaborating institutions involved in the study.

The baseline (T0) self-administered questionnaire consisted of a survey of lifetime and past 30 day mental disorders, sociodemographic characteristics, and various risk and resilience factors. The T1 self-administered questionnaire briefly evaluated soldiers' deployment experiences, such as stress exposure and traumatic brain injury (TBI). The T2 and T3 self-administered questionnaires were more comprehensive, focusing on evaluation of current mental disorders and risk and resilience factors.

Participants

At T0, 9949 soldiers were present for duty in the three BCTs. The large majority (95.3%) consented to participate in the PPDS, and most (86.0%) completed the T0 survey and agreed to linkage of survey responses to their Army/DoD records. These 8558 soldiers comprised the sample for cross-sectional analyses of T0 data. Of the T0 analysis sample, 7742 subsequently deployed to Afghanistan; they comprised the eligible sample for longitudinal analysis. Complete follow-up (T1, T2, and T3) data were available for 60.0% of the eligible longitudinal sample; all longitudinal analyses were conducted using data from these 4645 soldiers. Reasons for attrition included T0 respondents declining to consent to follow-up surveys, not being present at the participating posts at T1/T2 (e.g. due to reassignment to a different unit

or separation from the Army), or being unreachable at T3. Combined analysis weights were applied in all analyses that included (1) a propensity-based adjustment for baseline attrition due to incomplete surveys and inability to link to administrative data (e.g. due to absence of soldier consent), (2) post-stratification of these weights to map the sample of eligible PPDS soldiers to demographic and Army service characteristics of soldiers in the three combined BCTs that deployed to Afghanistan after the T0 interview dates, and (3) a propensity-based attrition adjustment to account for loss of respondents due to incomplete data in one or more of the three follow-up waves. Detailed information about weighting of Army STARRS data and procedures for handling missing item-level data can be obtained from a previous report [33].

Measures

Insomnia

The predictor of interest for this study was insomnia disorder at pre-deployment baseline (T0). The T0 self-administered questionnaire contained items adapted from the Brief Insomnia Questionnaire [34, 35], which evaluated lifetime and past 30 day insomnia disorder based on the *Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV)* criteria (omitting organic exclusion and diagnostic hierarchy rules). Lifetime insomnia disorder was considered present if the respondent endorsed (1) ever having problems getting to sleep, staying asleep, waking too early, or feeling so tired after a full night's sleep that it interfered with daytime activities; (2) ever experiencing a whole month or longer when such sleep problems were present at least three nights per week; and (3) ever experiencing at least "some" interference based on one or more of the following insomnia-related symptoms: daytime fatigue/sleepiness/low motivation, headaches/gastrointestinal distress, moodiness, reduced performance at work or school, and accident-proneness. Interference based on the same insomnia-related symptoms was assessed with respect to the preceding 30 days; those who endorsed at least "some" interference from one or more of the symptoms in the past 30 days were assigned a diagnosis of past 30 day insomnia disorder at T0. The T2 and T3 surveys also assessed past 30 day insomnia disorder.

PTSD and other mental disorder diagnoses

A six-item modified PTSD Checklist [36] (PCL) and a computerized version of the Composite International Diagnostic Interview Screening Scales (CIDI-SC) [37] were administered at T0 to assess lifetime and past 30 day *DSM-IV* mental disorders (omitting organic exclusion and diagnostic hierarchy rules). The Army STARRS clinical reappraisal study found satisfactory concordance between CIDI-SC/PCL diagnoses and independent diagnoses based on blinded structured clinical interviews for *DSM-IV* [38]. Diagnostic assessment focusing on past 30 day disorders was repeated at T2 and T3; however, diagnostic variables were not available at T1. Past 30 day PTSD diagnosis at T2 or T3 was one of the two outcomes of interest in this study. Models of this outcome controlled for PTSD diagnosis at T0, as well as other baseline diagnoses that could be confounded with insomnia (major depressive episode and generalized anxiety disorder [GAD]; see Data Analysis section).

Suicidal ideation

An expanded self-report version of the Columbia Suicide Severity Rating Scale (C-SSRS) [39] was administered at T0 to assess lifetime and past 30 day suicidal ideation, plans, and attempts. The same scale was used at T2 and T3 to assess occurrence of ideation, plans, and attempts during the preceding 30 days. The C-SSRS was not administered at T1. Endorsement of past 30 day suicidal ideation at T2 or T3 was the outcome of interest for this study; models of this outcome controlled for suicidal ideation at T0, as well as other baseline diagnoses that could be confounded with insomnia (major depressive disorder and GAD; see Data Analysis section).

Other baseline covariates

Models that estimated the associations of baseline insomnia disorder with post-deployment PTSD and suicidal ideation controlled for several other baseline variables, in addition to the baseline mental health variables described earlier. These included age, sex, race (white, black, Asian, or other), ethnicity (Hispanic or non-Hispanic), number of prior deployments (0, 1, 2, or more), and BCT. Given that insomnia can follow TBI, models also controlled for pre-deployment history of TBI. Stein *et al.* [40] described assessment of TBI in PPDS surveys and the derivation of variables characterizing TBI history. Following that study, lifetime head/neck/blast injuries that caused loss of consciousness of any duration were quantified as 0, 1, or 2 or more.

Covariates assessed at T1

The final models estimating associations of baseline insomnia with post-deployment PTSD and suicidal ideation also adjusted for several variables assessed on soldiers' return from deployment. These included deployment stress exposure, mental disorder symptoms experienced during the index deployment, and TBI sustained during the index deployment.

The T1 survey assessed frequency of stressful experiences during the index deployment [*e.g.* how many times did you ever … (1) *Go on combat patrols or have other dangerous duty (e.g. route clearance, clearing buildings, disarming civilians, working in areas that had IEDs)? … Fire rounds at the enemy or take enemy fire (either direct or indirect fire)?*]. Responses to items were discretized (0/1/2) and summed to quantify overall severity of combat/deployment stress (theoretical range = 0–16). Additional details about this scale can be obtained from a prior report [41].

Full diagnostic assessment was not conducted at T1; however, the T1 survey included five PCL items that evaluated frequency of repetitive, disturbing memories of stressful experiences; physical reactions to reminders of stressful experiences; feeling as if one's future would be cut short; difficulty concentrating; and feeling jumpy or easily startled. The T1 PTSD symptom score reflects the sum of ratings of these five items (theoretical range = 0–20; $\alpha = .81$). The T1 survey also contained seven items that assessed symptoms of major depressive episode and GAD. Respondents rated frequency of depressed mood/sadness, feeling discouraged, loss of interest/pleasure, worthlessness, feeling anxious/nervous, worrying about many different things, and difficulty controlling worry. As reported previously [35], the ratings of major depressive episode and GAD symptoms were highly internally consistent and thus collapsed into a combined

major depressive episode/GAD symptom scale (theoretical range = 0–28; α = .90).

Following a prior study [40], deployment-acquired TBI was characterized as None vs. Mild (alteration or loss of consciousness for <30 min and/or lapse of memory for <30 min) vs. moderate to severe (loss of consciousness for 30 or more minutes and/or lapse in memory lasting 30 or more minutes).

Data analysis

Weights-adjusted multivariable logistic regression was used to estimate cross-sectional associations of sociodemographic characteristics, prior deployment history, lifetime TBI, and past 30 day PTSD, GAD, and major depressive episode with past 30 day insomnia disorder at T0. Similar methods were used in longitudinal models evaluating associations of past 30 day insomnia disorder at T0 with past 30 day PTSD and past 30 day suicidal ideation at T2 or T3. A hierarchy of models adjusted for (1) sociodemographic characteristics and prior deployment history; (2) T0 status on the outcome of interest (PTSD or suicidal ideation), as well as other risk factors that might be confounded with T0 insomnia disorder (lifetime TBI, past 30 day major depressive episode, and past 30 day GAD); and (3) deployment experiences that might mediate associations of insomnia with post-deployment mental health (deployment stress, PTSD and major depressive episode/GAD symptoms during deployment, and deployment-acquired TBI). A final set of models added interactions of T0 insomnia with deployment stress severity; however, none of the interactions were significant (*p*s > .25; results available on request).

Models were tested in the full sample, as well as within subsamples of soldiers with no lifetime history of the outcome in question at T0. The subgroup models were pursued to evaluate the relationship between pre-deployment insomnia disorder to new onset of PTSD and suicidal ideation post-deployment.

Because PPDS data are clustered (by BCT and administration session) and weighted, standard errors (SEs) were generated using the design-based Taylor series linearization method. Design-based Wald chi-square tests were used to examine multivariate significance. The software R (version 3.1.3; R Development Core Team, 2016) [42] was used to conduct all analyses. *p* Values less than .05 (two-tailed) were considered statistically significant.

Results

Participant characteristics

Respondents were predominantly male (94.7% [*SE* = 0.5%]) and white (71.9% [*SE* = 0.8%]). Smaller proportions identified their race as black (12.0% [*SE* = 0.6%]), Asian (3.6% [*SE* = 0.3%]), or other (12.4% [*SE* = 0.5%]); and 15.9% (*SE* = 0.5%) reported their ethnicity as Hispanic. Mean age was 26.9 years (*SE* = 0.18).

Over half of the respondents reported prior deployments—24.2% (*SE* = 0.7%) indicated one previous deployment and 30.7% (*SE* = 1.0%) reported two or more. Prevalence of lifetime PTSD and suicidal ideation at T0 was 11.9% (*SE* = 0.5%) and 10.7% (*SE* = 0.3%), respectively. One-third of soldiers reported TBI(s) with loss of consciousness before the index deployment, with 14.9% (*SE* = 0.5%) endorsing one TBI and 20.2% (*SE* = 0.6%) endorsing two or more. Nearly one-fifth of respondents reported sustaining TBI(s) during the index deployment, with 18.0% (*SE* = 0.8%) reporting probable mild TBI and 1.2% (*SE* = 0.2%) reporting probable moderate-to-severe TBI.

Insomnia at pre-deployment baseline (T0)

Weighted prevalence of lifetime and past 30 day insomnia disorder at T0 was 20.7% (*SE* = 0.6%) and 15.2% (*SE* = 0.5%), respectively. Sex, number of prior deployments, lifetime TBI, and past 30-day major depressive episode, GAD, and PTSD each exhibited associations with past 30 day insomnia disorder (Table 1).

Associations of pre-deployment insomnia with post-deployment PTSD

Adjusting for sociodemographic characteristics and prior deployment history, pre-deployment past 30 day insomnia disorder was associated with increased odds of past 30 day PTSD at post-deployment assessment (i.e. T2 *or* T3; adjusted odds ratio [AOR] = 3.14, 95% confidence interval [CI] = 2.58% to 3.82%, $p < .0005$; Table 2, Model 1, "Full sample"). Addition of controls for other pre-deployment risk factors attenuated this association (AOR = 1.89, 95% CI = 1.54% to 2.33%, $p < .0005$; Table 2, Model 2, "Full sample"). Subsequent adjustment for deployment experiences further weakened the association of pre-deployment insomnia

Table 1. Characteristics associated with past 30 day insomnia disorder in the baseline sample of the Pre/Post Deployment Study (*N* = 8558)

	AOR (95% CI)	χ^2	*P*
Age	1.00 (0.98% to 1.01%)	0.19	.66
Sex		4.76	.03
Male	1.00		
Female	1.43 (1.04% to 1.98%)		
Race		4.56	.21
White	1.00		
Black	0.88 (0.70% to 1.11%)		
Asian	0.89 (0.53% to 1.50%)		
Other	1.19 (0.92% to 1.53%)		
Ethnicity		0.36	.55
Non-Hispanic	1.00		
Hispanic	0.93 (0.72% to 1.19%)		
Prior deployments		40.32	<.0005
Zero	1.00		
One	1.67 (1.42% to 1.97%)		
Two or more	1.42 (1.14% to –1.77%)		
Lifetime TBI		116.71	<.0005
None	1.00		
One	1.76 (1.41% to 2.19%)		
Two or more	2.27 (1.94% to 2.64%)		
30 Day PTSD		37.72	<.0005
No	1.00		
Yes	2.34 (1.79% to 3.07%)		
30 Day major depressive episode		70.71	<.0005
No	1.00		
Yes	4.32 (3.07% to 6.08%)		
30 Day GAD		25.89	<.0005
No	1.00		
Yes	2.45 (1.73% to 3.45%)		

Model also adjusted for BCT.

Table 2. Associations of pre-deployment insomnia with post-deployment PTSD, adjusting for sociodemographic characteristics and prior deployment history (all models), pre-deployment risk factors (Models 2 and 3), and deployment experiences (Model 3 only)

	Full longitudinal sample (n = 4645)				Subsample without lifetime PTSD at T0 (n = 4120)			
	AOR	95% CI	χ^2	P	AOR	95% CI	χ^2	P
Insomnia disorder—Model 1	3.14	2.58% to 3.82%	130.71	<.0005	2.42	1.88% to 3.12%	46.73	<.0005
Insomnia disorder—Model 2	1.89	1.54% to 2.33%	35.97	<.0005	2.04	1.58% to 2.64%	29.79	<.0005
Insomnia disorder—Model 3	1.50	1.19% to 1.89%	11.86	.001	1.55	1.17% to 2.07%	9.13	.003

Weights-adjusted logistic regression models were fit to estimate the association of pre-deployment 30 day insomnia disorder with 30 day PTSD at 3 or 9 months post-deployment (T2 or T3) among soldiers who completed surveys at all four waves (T0, T1, T2, and T3) of the Pre/Post Deployment Study (full longitudinal sample). Model 1 adjusted for age, sex, race, ethnicity, prior deployments, and BCT. Model 2 adjusted for the same variables as Model 1, plus PTSD status at T0 (30 day PTSD, lifetime but not 30 day PTSD, or no lifetime PTSD), lifetime TBI at T0, 30 day major depressive episode at T0, and 30 day GAD at T0. An interim model (results not presented) included all of the covariates from Model 2, plus deployment stress severity, deployment-acquired TBI, PTSD symptoms during deployment, and major depressive episode/GAD symptoms during deployment. Model 3 was identical to the interim model, except that nonsignificant pre-deployment risk factors and deployment experiences were excluded. An analogous procedure was used to estimate the association of pre-deployment insomnia disorder with *incident* PTSD at T2 or T3 (subsample without lifetime PTSD at T0).

with post-deployment PTSD; however, it remained statistically significant (AOR = 1.50, 95% CI = 1.19% to 1.89%, p = .001; Table 2, Model 3, "Full sample"). Similar results were obtained when the models were tested within the subsample of soldiers with no lifetime PTSD at T0 (i.e. new-onset of PTSD at T2 *or* T3; Table 2, Models 1–3, "Subsample without lifetime PTSD at T0").

Associations of pre-deployment insomnia with post-deployment suicidal ideation

Models adjusting for sociodemographic characteristics and prior deployment history indicated that past 30 day insomnia disorder at T0 was associated with increased odds of past 30 day suicidal ideation at T2 or T3 (AOR = 2.78, 95% CI = 2.07% to 3.74%, p < .0005; Table 3, Model 1, "Full sample"). Controlling for other pre-deployment risk factors resulted in attenuation of this association (AOR = 1.83, 95% CI = 1.32% to 2.53%, p < .0005; Table 3, Model 2, "Full sample"). Addition of deployment experiences to the model further weakened the association of pre-deployment insomnia with post-deployment suicidal ideation, but it remained significant (AOR = 1.43, 95% CI = 1.04% to 1.95%, p = .027; Table 3, Model 3, "Full sample"). Analogous results were obtained when the models were tested among soldiers who denied lifetime history of suicidal ideation pre-deployment (i.e. new onset of suicidal ideation at T2 *or* T3; Table 3, Models 1–3, "Subsample without lifetime ideation at T0").

Discussion

This study revealed that US Army soldiers with pre-deployment insomnia disorder were at increased risk of post-deployment PTSD and suicidal ideation. These associations were partly explained by co-occurring pre-deployment risk factors such as depression, and potential mediators such as deployment stress. However, even after accounting for these factors, pre-deployment insomnia was associated with 50% increased risk of PTSD and more than 40% increased risk of suicidal ideation following deployment. Among soldiers with no lifetime history of PTSD, pre-deployment insomnia was associated with 55% increased risk of incident PTSD; and among those with no lifetime history of suicidal ideation, pre-deployment insomnia was associated with 67% increased risk of onset of suicidal thoughts following deployment.

Insomnia was common in this population, with approximately one in five soldiers reporting lifetime insomnia and 15% endorsing past 30 day insomnia at the pre-deployment assessment. Prior deployments, lifetime TBI, and past 30 day major depressive episode, GAD, and PTSD were strongly associated with past 30 day insomnia diagnosis at baseline. Sleep problems present as common manifestations and are part of the diagnostic criteria of major depressive episode, GAD, and PTSD [43]. TBI is associated with numerous psychiatric disorders including insomnia, major depressive episode, PTSD, GAD, and suicidal behaviors [40]. People with TBI may have acute or permanent sleep problems possibly secondary to TBI, yet the mechanism remains elusive [44]. Previous studies of service members have found that sleep problems are prevalent following deployment, particularly among personnel with greater combat exposure [27].

Prospective findings that insomnia was associated with increased risk of PTSD and suicidal ideation at 3 or 9 months post-deployment add to evidence that insomnia is an independent risk factor for PTSD [45] and suicidality [4–7, 46, 47] including among military personnel [48–50]. These results converge with findings from the Millennium Cohort Study [22], which indicated that pre-deployment insomnia was associated with higher risk of post-deployment PTSD, independent of other risk factors. We confirm this prior finding and additionally provide evidence of an association between pre-deployment insomnia and post-deployment suicidal ideation.

Physiological, psychological, and genetic pathways have been proposed to explain the role of insomnia in the development of PTSD. Germain [51] asserts that hyperaroused sleep and dysregulated rapid eye movement sleep are markers of compromised resilience and can exacerbate PTSD after traumatic events. Polysomnographic data suggest the hyperarousal component of sleep disturbance worsens reexperiencing symptoms and emotional distress in PTSD [20]. Physiologically, the role of obstructive sleep apnea syndrome in PTSD is unclear due to both positive and negative findings in relation to PTSD [52, 53], but evidence indicates that sleep-disordered breathing negatively affects efficacy of PTSD treatment [54]. Genetic influences and structural changes in the brain are also found to associate with the severity of insomnia and levels of morbidity in PTSD. Heterozygosity in gamma-aminobutyric acid type A receptor β3 subunit gene is associated with higher levels of insomnia [55], whereas insomnia severity correlates with

Table 3. Associations of pre-deployment insomnia with post-deployment suicidal ideation, adjusting for sociodemographic characteristics and prior deployment history (all models), pre-deployment risk factors (Models 2 and 3), and deployment experiences (Model 3 only)

	Full longitudinal sample (n = 4645)				Subsample without lifetime ideation at T0 (n = 4119)			
	AOR	95% CI	χ^2	P	AOR	95% CI	χ^2	P
Insomnia disorder—Model 1	2.78	2.07% to 3.74%	46.22	<.0005	2.40	1.66% to 3.47%	21.41	<.0005
Insomnia disorder—Model 2	1.83	1.32% to 2.53%	13.06	<.0005	1.93	1.29% to 2.90%	10.15	.001
Insomnia disorder—Model 3	1.43	1.04% to 1.95%	4.91	.027	1.67	1.16% to 2.40%	7.57	.006

Weights-adjusted logistic regression models were fit to estimate the association of pre-deployment 30 day insomnia disorder with 30 day suicidal ideation at 3 or 9 months post-deployment (T2 or T3) among soldiers who completed surveys at all four waves (T0, T1, T2, and T3) of the Pre/Post Deployment Study (full longitudinal sample). Model 1 adjusted for age, sex, race, ethnicity, prior deployments, and BCT. Model 2 adjusted for the same variables as Model 1, plus suicidal ideation status at T0 (30 day ideation, lifetime but not 30 day ideation, or no lifetime ideation), lifetime TBI at T0, 30 day major depressive episode at T0, and 30 day GAD at T0. An interim model (results not presented) included all of the covariates from Model 2, plus deployment stress severity, deployment-acquired TBI, PTSD symptoms during deployment, and major depressive episode/GAD symptoms during deployment. Model 3 was identical to the interim model, except that nonsignificant pre-deployment risk factors and deployment experiences were excluded. An analogous procedure was used to estimate the association of pre-deployment insomnia disorder with *incident* suicidal ideation at T2 or T3 (subsample without lifetime suicidal ideation at T0).

decreased volume in the CA3/dentate hippocampal subfield in individuals with PTSD [56]. Taken together, these findings suggest that insomnia may be a sentinel signal of PTSD vulnerability. Active detection and management of insomnia among military personnel may help preserve resilience and prevent subsequent PTSD in this high-risk population. Future research that directly investigates these hypotheses is warranted.

The relationship between insomnia and suicide was first addressed over two decades ago [57]. Since then, evidence has linked insomnia to suicide in both the general population and in the military [58]. However, insomnia had not been previously investigated as a risk factor for suicidal ideation following combat deployment. Several pathways of the insomnia–suicidality relationship have been proposed, including serotonergic dysfunction [59], hopelessness related to chronic sleep problems [58], impaired executive function with impulsivity [60, 61], and insomnia-conferring mood dysregulation [22, 62, 63]. Our findings concur with a growing body of research suggesting that sleep disturbances, especially insomnia and nightmares, are associated with suicidal thoughts and behaviors independent of other preexisting psychiatric disorders [6, 46, 61, 64–66].

The finding that insomnia is prospectively associated with post-deployment suicidal ideation—including first onset of suicidal thoughts—is relevant to Army efforts to identify modifiable risk factors for suicidal behaviors and suicide [25, 29]. Detection of insomnia before deployment could facilitate targeting of risk mitigation programs for soldiers. Insomnia may warrant further exploration in suicide prevention if future research elucidates a strong linkage with suicidality. Treatments including behavioral sleep interventions and prazosin have been shown to reduce sleep problems and PTSD symptoms among military veterans [67]. Whether these interventions could help reduce suicidal thoughts and behaviors among service members is unknown and remains an important topic for future investigation.

This study has several strengths including its prospective design that incorporated assessment both before and at multiple points after combat deployment. The setting and sample offered the unique opportunity to examine risk associated with a prevalent clinical condition (insomnia) in conjunction with a common stress exposure associated with military service (combat deployment)—thus yielding potentially actionable findings relevant to the US Army. Finally, use of self-administered questionnaires might have provided more accurate prevalence estimates than studies relying on clinical encounter data. One study revealed that only 13% of participants ever consulted a provider for difficulties with sleep, whereas 42.3% reported having insomnia [68]. Nevertheless, service members may be more willing to seek treatment for insomnia than mental disorders [22], suggesting that clinical encounters focused on insomnia could serve as a gateway to engage patients in treatment for other common and treatable problems such as depression and PTSD.

Several study limitations merit careful consideration. For the evaluation of mental disorders, the use of self-administered questionnaires may be less accurate compared to assessment by a clinician or trained interviewer. This limitation is partly mitigated by use of well-validated assessment instruments and prior validation of PPDS diagnoses against structured clinical interviews. Another limitation of the data collection method is that self-reported data are vulnerable to recall and response bias. Although PPDS informed consent sessions included information regarding confidentiality protections, some soldiers may have been reluctant to acknowledge symptoms of mental disorders or suicidal ideation due to fear of negative consequences or stigma associated with these problems. Finally, despite demonstrating that insomnia predated PTSD and suicidal ideation in this prospective study—an important step toward assessing causality—these observational data do not prove causality.

Another weakness is that the survey assessment did not permit estimation of predictive effects of other sleep disturbances such as nightmares [31], or stratification of insomnia as early, middle, or late onset based on nocturnal hours. Several studies have suggested that nightmares may exacerbate suicidality through a different pathway [69–72]. Future research that makes these distinctions may clarify which elements of sleep disturbances are most relevant to development of PTSD and suicidality. Because of a lack of comparable outcome measures at the T1 assessment, we did not examine pre-deployment insomnia in relation to risk of PTSD or suicidal ideation during deployment. Additional investigation of that topic is needed in future studies. Finally, our sample primarily consists of white male soldiers less than 30 years who were exposed to a unique stressor (combat deployment); thus, the results cannot necessarily be generalized to the general population or to other stress exposures.

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In conclusion, we demonstrated that military personnel with pre-deployment insomnia exhibited increased risk of PTSD and suicidal ideation following combat deployment. Given the prevalence and impacts of insomnia, PTSD, and suicidality in the Armed Forces, greater attention to the early diagnosis and treatment of insomnia would be valuable. Future research is needed to better elucidate the mechanism of insomnia as a probable contributor to suicidality and PTSD, and to investigate whether intervention for insomnia can help prevent onset of PTSD and suicidal behaviors following military deployment.

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