



ORIGINAL ARTICLE

# The association of insomnia and sleep apnea with deployment and combat exposure in the entire population of US army soldiers from 1997 to 2011: a retrospective cohort investigation

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## Abstract

Since 2001, the United States has been engaged in the longest and most expensive overseas conflict in its history. Sleep disorders, especially insomnia and obstructive sleep apnea (OSA), are common in service members and appear related to deployment and combat exposure, but this has not been systematically examined. Therefore, the incidence of clinically diagnosed insomnia and OSA from 1997 to 2011 in the entire population of US Army soldiers was determined and associations of these disorders with deployment and combat exposure examined. This observational retrospective cohort study linked medical, demographic, deployment, and combat casualty data from all active duty US Army soldiers serving from 1997 to 2011 ( $n = 1\,357\,150$ ). The mediating effects of multiple known comorbid conditions were considered. From 2003 to 2011, there were extraordinary increases in incidence of insomnia (652%) and OSA (600%). Factors increasing insomnia risk were deployment (risk ratio [RR] [deployed/not deployed] = 2.06; 95% confidence interval [CI], 2.04–2.08) and combat exposure (RR [exposed/not exposed] = 1.20; 95% CI, 1.19–1.22). Risk of OSA was increased by deployment (RR [deployed/not deployed] = 2.14; 95% CI, 2.11–2.17), but not combat exposure (RR [exposed/not exposed] = 1.00; 95% CI, 0.98–1.02). These relationships remained after accounting for other factors in multivariable analyses. A number of comorbid medical conditions such as posttraumatic stress disorder and traumatic brain injury mediated a portion of the association between the sleep disorders and deployment. It is essential to determine underlying mechanisms responsible for these very large increases in insomnia and OSA and introduce effective preventive measures.

## Statement of Significance

The incidence of insomnia and sleep apnea in the entire population of US Army soldiers from 1997 to 2011 was determined, and the relationship between these disorders and deployment and combat exposure examined. From 2003 to 2011, there was an extraordinary increase in the incidence of insomnia (652%) and sleep apnea (600%) among soldiers. Higher insomnia risk was independently associated with both deployment and combat exposure. Increased risk of sleep apnea was associated with deployment but not combat exposure. A number of comorbid medical conditions such as posttraumatic stress disorder and traumatic brain injury mediated a portion of these associations. The underlying mechanisms responsible and effective preventive measures should be studied.

**Key words:** posttraumatic stress disorder; traumatic brain injury; depression; anxiety; stress; mediation analysis; comorbidities

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## Introduction

The incidence of insomnia and obstructive sleep apnea (OSA) in US military populations has risen dramatically in the 21st century [1–4]. For both disorders, Army personnel are affected to a much greater extent than members of the other military services [4]. The large increases over time in these sleep disorders are likely attributable to a variety of factors, one of which may be the large number of deployments of service members, especially US Army personnel, to Iraq and Afghanistan after the attacks on the World Trade Center and Pentagon in September 2001 [5]. As of June 2015, approximately 2.7 million service members (active duty, reserves, and National Guard) have served in wars in Iraq and Afghanistan [6]. Operations Iraqi Freedom, Enduring Freedom, and New Dawn (OIF/OEF/OND) represent the most sustained ground combat operations involving American forces since the Vietnam era [7]. Deployment-related factors associated with these operations such as physical and emotional stressors from hostile environments, mission-related maladaptive sleep practices, uncomfortable or otherwise inhospitable sleeping environments, and a culture that minimizes the importance of sleep may explain at least a portion of the upward trends in insomnia [8]. Increases in obstructive sleep apnea (OSA) are more difficult to explain based on increased operational activities, but may in part be due to the ongoing upward trend in service-members' body mass indices (BMI), a known cause of OSA, and/or associations between deployment-related sleep-disrupting medical/psychological illnesses such as traumatic brain injury (TBI), posttraumatic stress disorder (PTSD), depression, and/or pain [1, 8–13]. Blunt trauma is a significant predictor of OSA [14], and other studies have indicated the existence of a strong association between OSA, PTSD, and other medical disorders and injuries in military populations [15].

Survey research suggests the risk of poor sleep quality and quantity in service members increases as a function of the number of deployments and the amount of combat exposure while deployed [16–18]. Given the dramatic increases in sleep disorders in military populations, it has been suggested a systematic, longitudinal evaluation of the impact of deployments and military service on chronic sleep problems postdeployment should be conducted [19]. Some evidence suggests that deployed and postdeployed service members sleep less and the quality of their sleep is diminished compared with those with no deployment experience, but there is no definitive longitudinal evidence directly associating deployment with postdeployment sleep disorders [8, 20].

Since insufficient and/or disordered sleep is associated with numerous long-term physical- and mental-health problems including an increased risk of hypertension, diabetes, obesity, heart attack, stroke, depression, anxiety, substance abuse, PTSD, suicide, and all-cause mortality; and since sleep disorders often persist for years after deployments have ended, it is essential to understand the association between deployment and combat exposure with sleep disorders [8, 17, 18, 21, 22]. Therefore, the major objectives of this study were: (1) to provide a comprehensive assessment of the incidence of clinically diagnosed insomnia and OSA in the entire US Army; (2) to examine associations between insomnia/OSA and deployment and combat exposure; and (3) to assess the degree to which these relationships (if found) would be influenced by the mediating effects of relevant comorbid conditions such as PTSD and TBI [10, 13,

23–26] since this information is not currently available [8]. The Army was chosen as the population of interest for this study as this is the branch of the military with the greatest risk of sleep-related problems and the largest number of individuals who have served in combat theatres compared with other services [1, 2, 4, 27].

## Methods

This retrospective cohort study was approved by the Human Use Review Committee of the US Army Research Institute of Environmental Medicine. Participants included the entire population of soldiers who served in the US Army from 1997 through 2011 ( $n = 1\,357\,150$ ). Information on each soldier was obtained from the Total Army Injury and Health Outcomes Database (TAIHOD) which consolidates multiple personnel and health datasets from various Department of Defense agencies [28]. Information obtained for this investigation included individual soldier medical, demographic, deployment, and casualty data. Medical information included clinical encounters from the Standard Ambulatory Data Record, the Standard Inpatient Data Record, the Health Care Service Report-Institutional, Tricare Encounter Data-Institutional, Tricare Encounter Data-Non Institutional, and Comprehensive Ambulatory/Professional Encounter Record. Demographic information was provided by the Defense Manpower Data Center (DMDC) and physical characteristics from the Military Entrance Processing Command (MEPCOM) database. Deployment information was obtained from the Contingency Tracking System (CTS) and casualty data from the Army Casualty Information Processing System [29].

To define insomnia and OSA, appropriate International Classification of Diseases, Version 9, Clinical Modification (ICD-9-CM) codes were used. For insomnia, ICD-9-CM codes included 307.40, 307.41, 307.42, 327.00, 327.01, 307.02, 302.09, 780.50, 780.51, and 780.52. For OSA, ICD-9-CM codes included 327.20, 327.21, 327.22, 327.23, 327.24, 327.25, 327.26, 327.27, 327.29, 780.51, 780.53, and 780.57. Data for examination of comorbidities identified as potential confounders for development and/or persistence of sleep disorders were also obtained from TAIHOD databases [10, 23–26]. These conditions were depression, anxiety, adjustment reactions, acute reactions to stress, disturbances of conduct, PTSD, TBI, alcohol dependence/abuse, hypertension, gastroesophageal reflux disease, asthma, sleep-related movement disorders, diabetes, chronic pain, hyperthyroidism, fibromyalgia, and overweight/obesity. They were identified by specific ICD-9-CM codes (Supplementary Table S1).

To ensure soldiers with multiple OSA or insomnia codes were not counted more than once, OSA and insomnia were determined on a per soldier basis. For each soldier, all medical encounters during the time period of interest that had any of the ICD-9 codes specified for insomnia (or OSA) were identified. That is, if at least one ICD-9 code indicated insomnia (or OSA) was recorded during a medical encounter, then OSA or insomnia was flagged for that soldier. The earliest dated medical encounter flagged for either condition was considered the first incident insomnia/OSA encounter for that soldier.

Data from the deployment database (CTS) included start and end dates of each deployment, and these data were used to calculate the number of deployments and total amount of time deployed. A soldier was considered deployed if that soldier served

outside the United States at any time during his or her military service. Demographic data from DDMC included gender, date of birth, ethnicity/race, marital status, rank, educational level, unit identification code (UIC), and time in service (start date/end date). Data from the MEPCOM database included height and weight at entry to service. Data from the casualty database included proximate cause and date of death. The UIC at time of death was linked to casualty data.

Soldiers were considered combat exposed if they were in a unit (based on UIC) that experienced a combat-related death. This is a conservative definition because it is likely some units without combat-related deaths were exposed to combat. Not all soldiers in a unit with a combat-related death would be directly engaged in hostile actions (e.g. clerks, maintenance personnel, and supply), but it was expected that assignment in units where a combat death had occurred likely influenced sleep disorders in these individuals [12].

Data from soldiers with insomnia or OSA before 1997 were eliminated. Separate data sets were developed, and separate analyses performed for incident insomnia and incident OSA. Soldiers were followed from 1997 or the start of service until: (1) the first incident insomnia or OSA; or (2) when they separated from service; or (3) until December 31, 2011. Comorbid conditions (listed previously) were identified prior to deployment for all soldiers, and after the start of the first deployment for all soldiers who deployed. The overall incidence of insomnia and OSA was determined by year from 1997 to 2011, and linear regression was used to estimate the rate of change in the incidences of the two sleep disorders. If a soldier was diagnosed with both OSA and insomnia, that soldier would have been included as a case of OSA and as a case of insomnia in both models. However, the person-time contributed to both models would differ depending on whether insomnia or OSA occurred first. For example, if the incident insomnia diagnosis occurred after the incident OSA diagnosis, then the person-time contribution to the OSA analysis would be less than the person-time contribution to the insomnia analysis.

The Open Source Epidemiological Statistics package (Version 3.01) was used to examine crude (unadjusted) associations between the sleep disorders and deployment, combat exposure, and comorbid variables [30]. Statistical Analytic System (SAS) software (version 9.4, SAS Institute, Inc., Cary, NC) was used to calculate multivariable Poisson regressions to estimate adjusted

risk ratios and examine associations between the sleep disorders and covariates including months of deployment, combat exposure, number of pre- and post-deployment comorbidities, sex, race/ethnicity, age, educational level, marital status, military rank, time in service, and body mass index (BMI) at entry to service. Age was calculated from date of birth; BMI was calculated as weight/height [2].

Because of the known contribution of comorbidities to sleep disorders [8, 10, 13–15], mediation analyses were also conducted. Mediation analysis estimates the effect of a third (mediating) variable on the relationship between a dependent and independent variable. In this case, mediation analysis estimated the contribution of the number of comorbidities to the observed association between deployment and sleep disorders. The methods of VanderWeele and coworkers were used to calculate direct and mediating effects from outcome and mediator regression models; total effects and the proportion mediated were assessed [31–33]. Direct effects expressed the influence of deployment on the sleep disorders in the absence of comorbidities after deployment, while mediating effects expressed the influence of deployment on sleep disorders through the number of comorbidities. Regression models were generated using SAS software [31].

## Results

Figure 1 presents the incidence of insomnia and OSA in all active duty Army soldiers from 1997 to 2011. Linear regressions indicated that from 1997 to 2003, the incidence of insomnia and OSA increased at rates of 1.5 and 0.6 cases/1000 soldier-years, respectively. From 2003 to 2011, incidence of insomnia and OSA increased at rates of 8.2 and 3.5 cases/1000 soldier-years, respectively. In 2003, the incidence of insomnia was 9.6 cases/1000 soldier-years and in 2011 it was 72.2 cases/1000 soldier-years, a 652% increase. In 2003 the incidence of OSA was 4.3 cases/1000 soldier-years and in 2011 it was 30.1 cases/1000 soldier-years, a 600% increase. For the entire period, the overall incidence of insomnia and OSA was 11.9% and 5.1%, respectively.

Table 1 demonstrates that among the entire cohort of soldiers, risk of insomnia was higher among those who deployed compared with those who did not (risk ratio [RR] [deployed/not deployed] = 2.06; 95% confidence interval [95% CI],

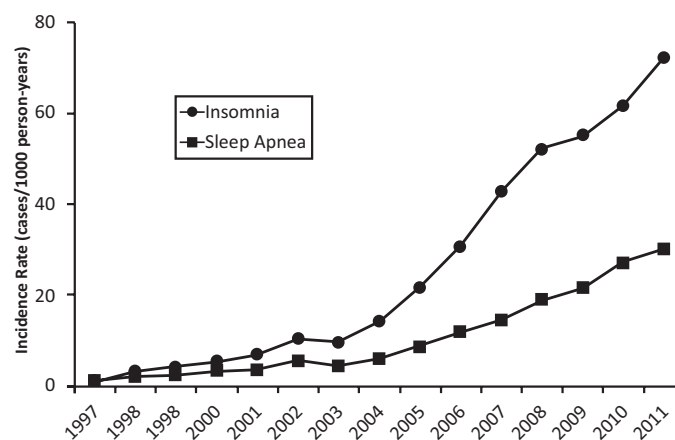


Figure 1. Incidence of insomnia and sleep apnea among US Army soldiers from 1997 to 2011.

Table 1. Crude (unadjusted) associations between sleep disorders risk and deployment and combat exposure variables

Sleep disorder	Variable	Strata	N	Proportion (%) with insomnia or sleep apnea	Relative risk (95% CI)
Insomnia	Deployed	No	879 707	8.1	1.00
		Yes	702 090	16.6	2.06 (2.04–2.08)
	Deployment months	None	879 707	8.1	1.00
		1–10 months	178 263	13.7	1.70 (1.67–1.72)
		11–20 months	325 722	18.3	2.27 (2.25–2.30)
		21–30 months	134 862	17.2	2.13 (2.11–2.16)
		>30 months	63 243	14.9	1.85 (1.82–1.89)
	Deployment Number	None	879 707	8.1	1.00
		1	399 226	17.2	2.13 (2.11–2.16)
		2	192 720	16.7	2.07 (2.05–2.10)
		3	71 910	16.0	1.99 (1.96–2.03)
		>3	38 234	11.0	1.37 (1.33–1.41)
	Combat exposed (deployed only)	No	562 041	16.0	1.00
		Yes	140 049	19.2	1.20 (1.19–1.22)
	Predeployment comorbidities	None	1 017 078	9.5	1.00
		1	312 995	13.4	1.41 (1.39–1.42)
		2	134 702	17.3	1.82 (1.80–1.84)
		3	65 818	20.1	2.11 (2.08–2.15)
		>3	51 204	24.4	2.56 (2.52–2.61)
	Postdeployment comorbidities (deployed only)	None	380 460	9.9	1.00
1		158 671	18.0	1.81 (1.78–1.84)	
2		75 591	26.9	2.70 (2.66–2.75)	
3		42 277	32.0	3.21 (3.15–3.27)	
>3		45 091	36.3	3.65 (3.58–3.72)	
Sleep apnea	Deployed	No	865 893	3.4	1.00
		Yes	716 009	7.2	2.14 (2.11–2.17)
	Deployment months	None	865 893	3.4	1.00
		1–10 months	178 910	6.0	1.79 (1.75–1.83)
		11–20 months	326 244	7.3	2.15 (2.11–2.18)
		21–30 months	141 817	8.3	2.45 (2.40–2.50)
		>30 months	69 038	8.2	2.42 (2.35–4.48)
	Deployment number	None	865 893	3.4	1.00
		1	397 394	6.5	1.93 (1.90–1.96)
		2	200 577	8.0	2.37 (2.33–2.41)
		3	77 058	8.9	2.63 (2.57–2.70)
		>3	40 980	7.4	2.18 (2.10–2.26)
	Combat exposed (deployed only)	No	572 843	7.2	1.00
		Yes	143 166	7.2	1.00 (0.98–1.02)
	Predeployment comorbidities	None	1 010 850	3.7	1.00
		1	3 10 673	6.4	1.75 (1.72–1.78)
		2	134 508	8.3	2.27 (2.22–2.32)
		3	67 611	9.1	2.50 (2.43–2.58)
		>3	58 260	11.7	3.21 (3.11–3.32)
	Postdeployment comorbidities (deployed only)	None	3 73 807	4.1	1.00
1		1 56 580	7.8	1.91 (1.87–1.96)	
2		76 459	10.7	2.62 (2.55–2.69)	
3		46 111	12.4	3.01 (2.92–3.10)	
>3		63 052	16.4	3.99 (3.90–4.09)	

2.04–2.08). Risk was greatest when a soldier had deployed for a total of 11–20 months (RR [deployed 11–20 months/not deployed] = 2.27; 95% CI, 2.25–2.30). Soldiers who deployed on only one occasion had the highest risk of insomnia. Among deployed soldiers, combat exposure increased insomnia risk (RR [combat exposed/not exposed] = 1.20, 95% CI=1.19–1.22). Deployment also increased OSA risk (RR [deployed/not deployed] = 2.14; 95% CI, 2.11–2.17) for up to 30 months or 3 deployments, after which it either changed little (months) or declined slightly (number). Among deployed soldiers, combat exposure was not associated with OSA risk (RR [combat

expose/not exposed] = 1.00, 95% CI = 0.98–1.02). The risk of both insomnia and OSA increased as the number of pre- or post-deployment comorbidities increased.

Table 2 presents the multivariable analyses (Poisson regressions) examining associations between sleep disorders and covariates for both the entire cohort of soldiers and the entire deployed soldier cohort. Among the entire cohort, insomnia risk increased up to 11–20 months of deployment then decreased. OSA risk was similar at 11–20 and 21–30 months of deployment then decreased at >30 deployment months. Pre- or post-deployment comorbidities increased the risk of both sleep

**Table 2.** Multivariable analysis of associations between insomnia and sleep apnea risk and covariates in the entire soldier population and the deployed soldier population

Variable	Strata	Entire soldier population RR (95% CI)		Entire deployed soldier population RR (95% CI)	
		Insomnia	Sleep apnea	Insomnia	Sleep apnea
Deployment	None	1.00	1.00	1.00	1.00
	1–10 months	1.59 (1.57–1.62)	1.75 (1.71–1.79)	1.27 (1.25–1.29)	1.22 (1.19–1.25)
	11–20 months	2.08 (2.05–2.10)	2.15 (2.11–2.19)	1.06 (1.04–1.08)	1.19 (1.16–1.22)
	21–30 months	1.82 (1.79–1.84)	2.15 (2.10–2.20)	0.84 (0.82–0.86)	1.02 (0.99–1.06)
	≥30 months	1.49 (1.46–1.52)	1.88 (1.83–1.94)		
Combat exposure	No			1.00	1.00
	Yes			1.19 (1.17–1.20)	1.00 (0.98–1.02)
Predeployment comorbidities	Continuous (n)	1.29 (1.29–1.29)	1.31 (1.30–1.31)	1.14 (1.14–1.15)	1.19 (1.18–1.20)
Postdeployment comorbidities	Continuous (n)	1.28 (1.27–1.28)	1.27 (1.27–1.28)	1.27 (1.27–1.27)	1.27 (1.26–1.27)
Sex	Men	1.00	1.00	1.00	1.00
	Women	1.09 (1.07–1.10)	0.51 (0.49–0.52)	1.05 (1.03–1.06)	0.50 (0.48–0.52)
Race/ethnicity	White	1.00	1.00	1.00	1.00
	Black	1.07 (1.06–1.08)	1.49 (1.47–1.51)	1.10 (1.08–1.11)	1.47 (1.44–1.50)
	Other	1.06 (1.05–1.07)	1.25 (1.22–1.27)	1.03 (1.02–1.04)	1.17 (1.14–1.19)
Age	<20 years	1.00	1.00	1.00	1.00
	20–24 years	1.01 (1.00–1.02)	1.26 (1.23–1.29)	1.05 (1.04–1.07)	1.29 (1.25–1.33)
	25–29 years	1.14 (1.12–1.16)	1.75 (1.70–1.81)	1.13 (1.11–1.15)	1.67 (1.61–1.73)
	30–34 years	1.15 (1.12–1.17)	1.70 (1.64–1.76)	1.10 (1.07–1.12)	1.55 (1.48–1.61)
	35–39 years	0.92 (0.90–0.95)	1.34 (1.29–1.40)	1.06 (1.02–1.10)	1.55 (1.46–1.62)
	≥40 years	0.81 (0.78–0.85)	1.24 (1.18–1.31)	1.00 (0.94–1.06)	1.40 (1.30–1.51)
Educational level	<HS	0.88 (0.87–0.90)	1.07 (1.04–1.11)	0.97 (0.95–1.00)	1.14 (1.09–1.19)
	HS Graduate	1.00	1.00	1.00	1.00
	College	1.10 (1.09–1.12)	0.94 (0.92–0.96)	1.05 (1.03–1.06)	0.89 (0.87–0.91)
	AdvDegree	0.95 (0.89–1.01)	1.00 (0.92–1.09)	0.87 (0.79–0.95)	0.83 (0.73–0.93)
Marital status	Single	1.00	1.00	1.00	1.00
	Married	1.15 (1.14–1.16)	1.26 (1.24–1.28)	1.15 (1.14–1.17)	1.22 (1.19–1.25)
	Div/Sep/Wid	1.20 (1.17–1.23)	1.24 (1.20–1.29)	1.20 (1.17–1.24)	1.17 (1.12–1.23)
Rank	Junior Enlisted (E1-E4)	1.00	1.00	1.00	1.00
	Senior Enlisted (E5-E9)	1.08 (1.05–1.11)	1.35 (1.31–1.39)	1.03 (1.00–1.06)	1.27 (1.23–1.31)
	Junior Officer (O1-O3)	0.79 (0.76–0.81)	1.17 (1.13–1.22)	0.67 (0.64–0.70)	0.97 (0.92–1.02)
	Senior Officer (O4-O9)	1.45 (1.24–1.70)	2.46 (2.11–2.87)	0.80 (0.62–1.04)	1.57 (1.25–1.98)
Time in service	≤1 years	1.00	1.00	1.00	1.00
	1–3 years	0.78 (0.77–0.80)	1.36 (1.32–1.40)	1.07 (1.04–1.10)	1.63 (1.57–1.69)
	3–5 years	0.93 (0.91–0.95)	1.63 (1.59–1.69)	1.14 (1.11–1.16)	1.86 (1.79–1.92)
	5–7 years	1.12 (1.09–1.15)	2.34 (2.26–2.42)	1.43 (1.39–1.47)	2.84 (2.73–2.96)
	>7 years	1.10 (1.07–1.13)	2.37 (2.28–2.46)	1.33 (1.29–1.38)	2.74 (2.61–2.86)
BMI (at entry to service)	Underweight	1.02 (0.99–1.06)	0.77 (0.72–0.83)	1.03 (0.99–1.07)	0.77 (0.70–0.84)
	Normal	1.00	1.00	1.00	1.00
	Overweight	0.99 (0.98–1.00)	1.31 (1.29–1.33)	1.00 (0.99–1.01)	1.28 (1.26–1.31)
	Obese	1.03 (1.02–1.05)	1.69 (1.66–1.73)	1.03 (1.02–1.05)	1.63 (1.59–1.67)

RR = relative risk, 95% CI = 95% confidence interval; HS = high school; Adv = advanced; Div = divorced; Sep = separated; Wid = widowed.

disorders. Among all deployed soldiers, risk of both insomnia and OSA increased at 11–20 months of deployment and then decreased progressively for longer deployments. Combat exposure increased insomnia risk but not OSA risk. Pre- or post-deployment comorbidities increased the risk of both sleep disorders. Overweight or obesity based on BMI at entry to service substantially increased the risk of OSA, but not insomnia.

The results of the mediation analyses are presented in [Table 3](#). Among the entire population, the longer a soldier was deployed the more likely it was that the effect of deployment on insomnia and OSA was mediated through the number of comorbidities and less through the direct effect of deployment, although the direct effect of deployment remained. Among the deployed cohort, the results were similar in that the longer a

soldier was deployed the effect of deployment on insomnia or OSA was more likely to be mediated by the comorbidities assessed. However, the direct effect of deployment on insomnia risk was actually lower at >30 deployment months (RR = 0.84) compared with the 1–10 month baseline (RR = 1.00). For OSA, the direct effect of deployment was similar at the 1–10 month baseline (RR = 1.00) and at >30 months of deployment (RR = 1.02).

[Table 4](#) shows the associations between the risk of insomnia and sleep apnea for each comorbid condition. Virtually all comorbid conditions increased insomnia and OSA risk with the exception of alcohol dependence/abuse. Five leading conditions that more-than doubled or tripled the risk of insomnia were, in descending order: (1) sleep-related movement disorder; (2) PTSD; (3) anxiety; (4) adjustment reaction; and (5) acute reaction

**Table 3.** Effects of deployment on sleep disorders considering mediating effects of comorbidities

Group	Variable	Strata	Insomnia				Sleep Apnea			
			1–10 months	11–20 months	21–30 months	>30 months	1–10 months	11–20 months	21–30 months	>30 months
Entire soldier population	Direct effect—effect of deployment on sleep disorder in absence of comorbidities after deployment (RR)	Not deployed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Deployed	1.59	2.08	1.82	1.49	1.75	2.15	2.15	1.88
	Mediating effect—effect of deployment on sleep disorder through the number of comorbidities (RR)	Not deployed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Deployed	1.20	1.26	1.34	1.40	1.22	1.30	1.40	1.47
	Total effect—total effect of deployment on sleep disorder (RR)	Not deployed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Deployed	1.91	2.62	2.43	2.09	2.13	2.80	3.00	2.76
	Proportion of the effect of deployment on sleep disorder mediated through number of comorbidities (%)		35	33	43	55	34	34	43	50
Entire deployed soldier population	Direct effect—effect of deployment on sleep disorder in absence of comorbidities after deployment (RR)	1–10 months		1.00	1.00	1.00		1.00	1.00	1.00
		Other deployed time		1.27	1.06	0.84		1.22	1.19	1.02
	Mediating effect—effect of deployment on sleep disorder through the number of comorbidities (RR)	1–10 months		1.00	1.00	1.00		1.00	1.00	1.00
		Other deployed time		1.05	1.11	1.15		1.06	1.31	1.18
	Total effect—total effect of deployment on sleep disorder (RR)	1–10 months		1.00	1.00	1.00		1.00	1.00	1.00
		Other deployed time		1.33	1.17	0.97		1.29	1.34	1.21
	Proportion of the effect of deployment on sleep disorder mediated through number of comorbidities (%)			18	66	*		25	45	88

RR = relative risk.

\*Direct and mediating effects are not in the same direction; therefore, the effect of deployment on insomnia is negatively mediated through the number of comorbidities and the proportion mediated is unreliable.

to stress. The five leading conditions that more than doubled the risk of OSA were: (1) hypertension; (2) gastroesophageal reflux disease (GERD); (3) diabetes; (4) PTSD; and (5) overweight/obesity.

## Discussion

This study demonstrated that from 2003 to 2011, a period when the United States was continuously engaged in warfare and soldiers were regularly and repeatedly deployed to combat theatres in great numbers, there were extraordinary increases in insomnia and OSA in the Army population. During this period, the incidence of insomnia increased 652%, whereas the incidence of OSA increased 600% among all US Army soldiers. Soldiers who were deployed had more than twice the risk of being diagnosed with insomnia (RR = 2.06; 95% CI, 2.04–2.08) or OSA (RR = 2.14; 95% CI, 2.11–2.17) compared with their nondeployed counterparts. The risk of developing either insomnia or OSA was greatest when soldiers were deployed for 11–20 months, a duration usually reached during or after a first or second deployment, after which it declined somewhat. Combat exposure independently

increased the risk of insomnia (RR = 1.19; 95% CI, 1.17–1.20) but not OSA (RR = 1.00; 95% CI, 0.98–1.02). For both sleep disorders, the longer a soldier was deployed the more likely the effect of deployment was mediated through various comorbidities and less by a direct effect of deployment. The comorbidities considered in the mediation analyses included depression, anxiety, acute reactions to stress, PTSD, TBI, overweight/obesity, and a number of other illness known to be associated with sleep disorders in military personnel and civilians [10, 23–26].

That combat exposure increased the risk of developing insomnia but not OSA could be attributable to the different nature of these disorders. There are multiple causes of insomnia including various mental disorders, limb movement disorders, poor sleep hygiene, and to a lesser extent, a variety of medical and neurological conditions [34]. Several of these could have been affected by combat exposure. However, OSA is a breathing disorder most-often characterized by an anatomical defect—narrowing of the upper airway—that impairs normal ventilation during sleep. As a result, OSA is typically associated with biological factors such as being overweight or obese,

**Table 4.** Associations between sleep disorders and comorbid conditions

Comorbid condition	Strata	Insomnia			Sleep apnea		
		N	Incidence (%)	Relative risk (95% CI)	N	Incidence (%)	Relative risk (95% CI)
Depression	No	1 397 107	10.1	1.00 (reference)	1 377 519	4.5	1.00 (reference)
	Yes	184 690	25.3	2.51 (2.48–2.53)	204 383	9.2	2.04 (2.01–2.08)
Anxiety	No	1 408 605	9.9	1.00(reference)	1 386 404	4.4	1.00 (reference)
	Yes	173 192	27.8	2.82 (2.79–2.85)	195 498	9.9	2.24 (2.21–2.28)
Adjustment reaction	No	1 287 539	9.1	1.00 (reference)	1 264 098	4.4	1.00 (reference)
	Yes	294 258	24.0	2.63 (2.61–2.66)	317 804	8.1	1.83 (1.81–1.86)
Acute reactions to stress	No	1 546 205	11.4	1.00 (reference)	1 264 403	5.0	1.00 (reference)
	Yes	35 592	29.9	2.61 (2.57–2.66)	40 281	9.7	1.93 (1.87–1.99)
Disturbances of conduct	No	1 568 209	11.8	1.00 (reference)	1 566 413	5.1	1.00 (reference)
	Yes	13 588	19.7	1.66 (1.61–1.72)	15 489	7.1	1.39 (1.32–1.48)
PTSD	No	1 526 062	10.9	1.00 (reference)	1 511 484	4.7	1.00 (reference)
	Yes	55 735	37.5	3.44 (3.40–3.48)	70 418	14.9	3.19 (3.13–3.25)
TBI (moderate/severe)	No	1 564 391	11.7	1.00 (reference)	1 562 083	5.1	1.00 (reference)
	Yes	17 406	25.7	2.20 (2.15–2.26)	19 819	11.0	2.18 (2.09–2.26)
TBI (mild)	No	1 491 926	11.4	1.00 (reference)	1 483 822	5.1	1.00 (reference)
	Yes	89 871	18.1	1.58 (1.56–1.60)	98 080	5.8	1.15 (1.12–1.18)
Alcohol dependence/abuse	No	1 443 238	11.5	1.00 (reference)	1 434 003	5.2	1.00 (reference)
	Yes	138 559	15.8	1.38 (1.36–1.40)	147 899	4.9	0.95 (0.92–0.97)
Hypertension	No	1 465 186	11.2	1.00 (reference)	1 459 097	4.1	1.00 (reference)
	Yes	116 611	20.7	1.86 (1.83–1.88)	122 805	17.8	4.37 (4.31–4.44)
GERD	No	1 478 674	11.1	1.00 (reference)	1 459 097	4.4	1.00 (reference)
	Yes	103 123	22.1	1.99 (1.96–2.01)	122 805	15.4	3.54 (3.48–3.59)
Asthma	No	1 480 754	11.4	1.00 (reference)	1 477 345	4.7	1.00 (reference)
	Yes	101 043	18.2	1.59 (1.57–1.62)	104 557	11.5	2.46 (2.42–2.51)
Sleep-related movement disorder	No	1 577 527	11.8	1.00 (reference)	1 576 045	4.9	1.00 (reference)
	Yes	4 270	41.3	3.51 (3.38–3.64)	5857	56.4	11.42 (11.16–11.69)
Diabetes	No	1 566 253	11.8	1.00 (reference)	1 565 990	5.0	1.00 (reference)
	Yes	15 544	18.9	1.61 (1.55–1.65)	15 912	17.1	3.42 (3.30–3.54)
Chronic pain	No	1 553 310	11.6	1.00 (reference)	1 544 407	4.9	1.00 (reference)
	Yes	28 487	26.9	2.33 (2.28–2.37)	37 495	12.8	2.58 (2.51–2.65)
Hyperthyroidism	No	1 576 662	11.8	1.00 (reference)	1 576 314	5.1	1.00 (reference)
	Yes	5135	21.4	1.81 (1.72–1.92)	5588	13.3	2.61 (2.44–2.80)
Fibromyalgia	No	1 482 069	11.4	1.00 (reference)	1 476 140	4.7	1.00 (reference)
	Yes	99 728	19.1	1.68 (1.66–1.71)	105 762	11.5	2.46 (2.42–2.51)
Overweight/obesity	No	1 388 340	10.9	1.00 (reference)	1 378 449	4.1	1.00 (reference)
	Yes	193 457	18.6	1.71 (1.68–1.72)	203 453	12.3	3.01 (2.98–3.06)

PTSD = posttraumatic stress disorder; TBI = traumatic brain injury; GREED = gastroesophageal reflux disease.

or in more extreme cases, diseases such as transient ischemic attack, stroke, coronary artery disease, congestive heart failure, arrhythmias, refractory hypertension, and Type 2 diabetes [35]. It is likely that a portion of the increase in OSA we observed is related to the increased incidence of overweight/obesity in the US Army as it increased substantially from 2003 (2.7%) to 2010 (6.5%) [36]. However, since the severity of obesity/overweight in Army personnel is markedly less than in the general population (6.5% of Army [36] versus approximately 36% of the general population [37] were obese in 2010), the potentially confounding influence of BMI is likely quite small. Thus, it is not surprising that the effect of deployment was still significant after controlling for overweight/obesity in the multivariable analysis.

The observation that the risk of clinically diagnosed insomnia was higher in deployed versus nondeployed soldiers is consistent with studies based on survey data which indicate sleep is adversely affected during deployment and thereafter [5, 18, 38–40]. Sleep can be compromised acutely and chronically by multiple factors associated with deployment and combat [8].

That the risk of developing a sleep disorder was reduced in longer deployments relative to shorter deployments (or following several deployments) appears contrary to some prior research [1, 38, 41]. However, the apparent inconsistency could be due to the fact that service members with shortened sleep duration or insomnia are less likely to deploy [42], largely because only soldiers judged healthy by medical personnel are allowed to deploy. Thus, healthy soldiers who deploy and then develop serious sleep disorders could be excluded from later deployments, leaving their more resilient and healthier peers to deploy subsequently.

That soldiers with longer deployments developed more medical comorbidities associated with sleep disorders is consistent with previous research on soldiers who served in Vietnam and the Persian Gulf War [43–50]. These studies show deployment stressors and exposure to combat result in an increased risk of mental health issues and other problems including the development of PTSD, major depression, substance abuse, impairment in social functioning, workplace difficulties, and a general increase in the use of health care services [43–50]. Thus, it is not

surprising exposure to combat in Iraq and Afghanistan was associated with increased rates of depression, PTSD, and alcohol abuse, as well as physical injuries [11, 51]. These deployments often exposed service members to a significant number of combat experiences such as being shot at, observing wounded colleagues, handling dead bodies, or knowing personnel who were injured or killed. Previous studies have shown that insomnia is associated with service-related illnesses [10], as well as a host of medical problems [23], and OSA in service members is known to be comorbid with TBI, PTSD, psychiatric disorders, and insomnia [5].

An unexpected finding of the present study was that as length of deployment increased the mediating effect of comorbidities on both insomnia and OSA increased. Concurrently, the direct effect of deployment on insomnia and OSA also initially increased with deployment time, but then decreased with longer deployment times. Longer deployments led to more comorbidities, and these comorbidities had a greater impact on sleep-disorder risk over time compared with the risk imposed by deployment alone. Although only soldiers considered to be healthy are deployed, it is possible that these soldiers may have nevertheless been developing medical and mental-health issues (comorbidities) that were not initially considered serious enough to prevent deployment even though they were beginning to result in sleep disorders. Further research is necessary to clarify this issue.

### Limitations

This epidemiological study could not establish the underlying cause of the observed deployment- or combat-related increases in insomnia and OSA. In addition, insomnia and OSA share various symptoms such as unrefreshing sleep, daytime sleepiness, fatigue, or general sleep difficulty, and as such, the increases in diagnoses of one of these conditions could be a secondary result of the increased diagnoses of the other. Another limitation is that this study could only examine the incidence of sleep disorders and comorbidities diagnosed by medical care providers when soldiers presented for medical care. It is likely some soldiers treated themselves or did not seek medical care and, therefore, the actual incidence of these disorders may be an underestimate. It should be noted the diagnostic and epidemiological information contained in the International Classification of sleep disorders was updated in 2005 [52], and although it is unlikely that this change would have affected the general relationship between sleep disorders and deployments/combat-exposure, it could have affected the overall prevalence rates reported here. For instance, the ICD coding of “snoring” is obscure, and as a consequence, some cases in the sleep apnea group may have been included simply due to a complaint of snoring, as opposed to the presence of a clinically significant problem of disordered breathing. It should be noted that we did not include in our case definition of OSA the recommended ICD-9 code for snoring (786.09). Finally, we did not examine Current Procedural Terminology (CPT) codes for polysomnography. A diagnosis of OSA with a CPT code for polysomnography would have been a more definitive OSA diagnosis, but many individuals elect to forgo the test for convenience and time considerations. We would likely have underestimated the incidence of OSA using polysomnography and thus examined the OSA clinical codes which could have

involved diagnoses on the basis of symptoms, signs, and possibly sleep studies.

### Conclusions

This study found extraordinary increases in insomnia and OSA in US Army soldiers from 2003 to 2011 when the United States was intensively engaged in multiple conflicts. For insomnia, these increases were associated with deployment as well as exposure to combat, whereas increases in OSA were only associated with deployment. Deployment, independent of other comorbid conditions such as PTSD, TBI, and depression, was strongly associated with the incidence of insomnia and OSA. Given the substantial risk of insomnia and OSA among deployed soldiers, it is essential to determine the underlying mechanisms responsible.

### Supplementary Material

Supplementary material is available at *SLEEP* online.

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