J Behav Med (2015) 38:544–555
DOI 10.1007/s10865-015-9627-4

Associations between sleep difficulties and risk factors for cardiovascular disease in veterans and active duty military personnel of the Iraq and Afghanistan conflicts

Christi S. Ulmer[1,2] · Hayden B. Bosworth[1,2] · Anne Germain[4] · Jennifer Lindquist[1] · Maren Olsen[1,2] · Mira Brancu[3] · the VA Mid-Atlantic Mental Illness Research Education and Clinical Center Registry Workgroup · Jean C. Beckham[2,3]

Received: August 19, 2014 / Accepted: March 3, 2015 / Published online: March 27, 2015

Abstract Recent evidence suggests that sleep disturbance may play an important role in the development of cardiovascular disease (CVD). Despite the prevalence of sleep complaints among service members of recent military conflicts, few studies have examined associations between sleep and risk factors for CVD in this population. Symptom checklist items regarding distress about "trouble falling asleep" and "restless/disturbed sleep" were used as proxies for sleep onset and maintenance difficulties to examine these associations in US military service members of recent conflicts. Veterans having both sleep onset and maintenance difficulties had greater odds of being a current smoker and having psychiatric symptoms and diagnoses. Increased odds of a self-reported hypertension diagnosis and elevated systolic blood pressure were also found in certain subsets of this sample. Findings highlight the need for greater recognition of sleep difficulties as a CVD risk factor in a population known to be at increased risk for this condition.

Keywords Sleep · Cardiovascular disease · Hypertension · Veterans · Insomnia

✉ Christi S. Ulmer
christi.ulmer@va.gov

[1] HSR&D (152), Durham Veterans Affairs Medical Center, 508 Fulton Street, Durham, NC 27705, USA

[2] Department of Psychiatry and Behavioral Sciences, Duke University Medical Center, Durham, NC, USA

[3] VISN 6 Mental Illness Research, Education, and Clinical Center S, Durham, NC, USA

[4] Departments of Psychiatry and Psychology, University of Pittsburgh, Pittsburgh, PA, USA

Introduction

Sleep disturbance is a primary complaint of US service members deployed to recent conflicts. About two-thirds of those deployed to Iraq or Afghanistan endorse symptoms of insomnia upon their return (Amin et al., 2010). Among those meeting diagnostic criteria for posttraumatic stress disorder (PTSD), the prevalence of insomnia and other sleep difficulties is even greater. An estimated 10–25 % of Veterans deployed to Iraq and Afghanistan have returned with PTSD (Tanielian & Jaycox, 2008), and up to 90 % of these Veterans are likely to endorse difficulty maintaining sleep (Neylan et al., 1998).

In recent years, mounting evidence suggests that sleep disturbance may play an important role in the development of cardiovascular disease (CVD), and US military veterans are at increased risk for many of the behavioral, physiological, and psychiatric risk factors for CVD examined in civilian samples. Few studies, however, have directly examined associations between sleep disturbance and risk factors for CVD in US military service members. Research findings in several studies suggest a greater prevalence of CVD and poorer health among Veterans relative to their civilian counterparts (Agha et al., 2000; Cohen et al., 2009a, 2009b; Hoerster et al., 2012; Kazis et al., 1999). In the Millennium Cohort, a registry of military personnel serving since 9/11, deployers with multiple combat exposures were at significantly greater risk of incident HTN relative to deployers without combat exposure, and both deployment and combat exposure were found to be independent predictors of HTN ($N > 36{,}000$) (Granado et al., 2009). Combat deployers were also at increased risk for new-onset CHD at follow-up, and a positive PTSD screen at baseline was associated with newly self-reported CHD at follow-up ($N = 27{,}794$) (Crum-Cianflone et al., 2014). Relative to those with no

mental health diagnoses, the odds of HTN among Veterans of recent conflicts diagnosed with PTSD ranges from 1.56 to 2.99, depending upon gender and model adjustments (Cohen et al., 2009a, 2009b). These findings are consistent with research in Vietnam-era Veterans who were assessed in 1985 and again in 2000. Those with a PTSD diagnosis at baseline were twice as likely to have died of early-onset heart disease at the 15-year follow-up relative to their non-PTSD counterparts (Boscarino, 2008).

Prospective relationships between sleep difficulties and future CVD have been demonstrated across various aspects of disturbed sleep, including short sleep duration, poor sleep quality, and insomnia in civilian populations. In a study of US adults (N = 135,685) followed for almost 13 years, shorter (≤5 h/day) and longer (≥9 h/day) sleepers of both sexes had an increased risk (vs. 7 h/day) of all-cause and CVD mortality (Kim et al., 2013). In a prospective study of Dutch adults (N = 20,432) followed for 10–15 years, those reporting short sleep (≤6 h) at baseline were at 15 % greater risk of developing CVD and 23 % greater risk of coronary heart disease (CHD) relative to those sleeping 7 h (Hoevenaar-Blom et al., 2011). In those reporting the combination of both short sleep duration and poor sleep quality, these increased risks climbed to 63 % for CVD and 79 % for CHD. Similar findings were reported in a prospective study of Japanese adults (N = 98,634) (Ikehara et al., 2009), and in a community-based study of Taiwanese adults both long sleep (≥9 h); in both, insomnia symptoms were associated with an increased risk of incident CVD events (i.e., CHD and stroke) over a 15 year follow-up period (Chien et al., 2010).

The relationship between sleep disturbance and CVD observed in these epidemiological studies is mirrored by a growing body of literature showing both cross-sectional and longitudinal associations between sleep disturbance and specific risk factors for CVD, such as hypertension. For example, even after adjusting for depression, anxiety and other sleep disorders, the prevalence of hypertension in community-based insomniacs is more than three times that of normal sleepers [odds ratio 3.18 (CI 1.90–5.32)] (Taylor et al., 2007). Among those reporting poor sleep quality, the prevalence of HTN is considerably higher (87.1 %) than those reporting good sleep quality (35.1 %) (Fiorentini et al., 2007). In short sleepers (≤5 h) the risk of HTN is more than double that of longer sleepers, and those reporting the combination of insomnia and short sleep duration are at increased risk of HTN ranging from three to five times that of normal sleepers, depending on sleep duration (Gangwisch et al., 2006). In experimental research paradigms, studies of sleep deprivation in healthy adults showed an increase in both systolic and diastolic blood pressure following total sleep deprivation (Carrington & Trinder, 2008; Robillard et al., 2011). In other studies, short sleep duration was associated with the metabolic syndrome (Hall et al., 2008), carotid intima-media thickness (Wolff et al., 2008), and inflammation (Patel et al., 2009), biomarkers of CVD.

Behaviorally-based risk factors for CVD, such as nicotine use and body mass index, are also associated with sleep difficulties. In US adults, short sleepers are more likely to be a current or former smoker, more likely to be obese, more likely to endorse symptoms of depression and anxiety, and are less physically active (Krueger & Friedman, 2009). Current smokers are more likely to report short sleep duration and poor sleep quality compared to never smokers (Mehari et al., 2014). Current smokers sleeping ≤6 or ≥9 h smoke significantly more packs of cigarettes per day than those sleeping 7 h (Krueger & Friedman, 2009) and report greater difficulty with sleep onset, sleep maintenance, and daytime sleepiness (Phillips & Danner, 1995). Smokers spend a lesser percentage of their total sleep time in the most restorative sleep phases relative to non-smokers, and this sleep architecture pattern is related to smokers' subjective reports of less restful sleep (Zhang et al., 2008). Higher body mass index is associated with both objectively measured (Lauderdale et al., 2009) and perceived short sleep duration (Wheaton et al., 2011).

Certain psychiatric conditions increase CVD risk as well. Sleep disturbance is a prominent feature of both depression and anxiety, which are in turn associated with CVD. In fact, depression is an independent risk factor for the development of CVD (Sowden & Huffman, 2009; Schnatz et al., 2011; Van der Kooy et al., 2007; Whang et al., 2009), and the combination of depression and anxiety seems to compound this risk in both veteran (Scherrer et al., 2010) and civilian populations (Fan et al., 2008). A recent twin study in Vietnam-era Veterans found that the incidence of CHD in twins with PTSD at the end of a 13-year follow-up period was double that of their non-PTSD counterparts (Vaccarino et al., 2013). Among Veterans of the Iraq and Afghanistan conflicts using VA services, the prevalence of cardiovascular risk factors in Veterans with mental health diagnoses is significantly higher than Veterans without mental health diagnoses (Cohen et al., 2009a, 2009b).

The collective findings summarized above implicate sleep disturbance as a contributing factor for CVD among recent military service members, and may inform our understanding of the seemingly higher rates of CVD seen in older military Veterans. Since few studies have focused on sleep and CVD risk factors in US military service members, we sought to examine the relationship between sleep difficulties and the following CVD risk factors (smoking status, pack years, BMI, self-reported hypertension diagnosis, hypertension medication use, clinic-based blood pressure readings, symptoms of depression and PTSD, and diagnosis of depression and PTSD) in the relatively

younger service members of the Iraq and Afghanistan conflicts. Sleep difficulties were operationalized as: (1) distress about sleep onset difficulty ("minimal" vs. "moderate to severe") over the previous 7 days; and (2) distress about restless or disturbed sleep ("minimal" vs. "moderate to severe") over the previous 7 days. We hypothesized that, relative to those endorsing only minimal distress about sleep difficulties, participants endorsing moderate to severe distress would be more likely: (1) to be prescribed antihypertensive medications; (2) to have higher blood pressure readings; (3) to report a diagnosis of hypertension; (4) to be a current smoker; (5) to report more years of smoking (greater pack years); (6) to be overweight; (7) to endorse symptoms of depression; and (8) to endorse symptoms of PTSD.

Methods

Procedures and participants

Data for this study was collected as part of an ongoing multisite study of military personnel (current $N > 3000$) who have served since September 11, 2001. The study was conducted by the Department of Veterans Affairs (VA) Veterans Integrated Service Network (VISN) 6 Mental Illness Research, Education and Clinical Center (MIRECC). Study participants were recruited using fliers, advertisements, VA clinic referrals and invitational letters which described a study on deployment and adjustment. Institutional Review Board approval was obtained at each participating study site. Following a complete description of the study, informed consent was obtained from each study participant. Data was collected during up to two study visits between June 30, 2005 and June 14, 2011 and included completion of paper, pencil or computer administered questionnaires, and a review of medical records. Study participants included both active duty military personnel and Veterans.

Measures

Demographic and deployment characteristics

Study participants provided demographic information in addition to military service information, including the branch of military service, era of military service, and the number and location of deployments.

Sleep difficulties

Sleep difficulties were assessed using 2 items from the Symptom Checklist-90-Revised (SCL-90-R: Derogatis, 1994), which was administered as part of the parent study protocol. The SCL-90-R is a 90-item self-report symptom inventory designed to measure a range of psychological symptoms and distress. It was designed for use with both community and psychiatric populations. Sleep onset difficulties were evaluated with the item: "In the past 7 days, how much were you distressed by trouble falling asleep?" Sleep maintenance difficulties were evaluated with the item: "In the past 7 days, how much were you distressed by sleep that is restless or disturbed?" Respondents were provided with the following response set for each of the sleep difficulty items: "not at all"; "a little bit"; "moderately"; "quite a bit"; "extremely". For purposes of analyses, these items were dichotomized into the following categories: "Minimal" and "Moderately to Severe". The "Minimal" sleep difficulties category was comprised of "not at all" and "a little bit", and the "Moderate to Severe" sleep difficulties category was comprised of "moderately", "quite a bit" and "extremely". Previous research suggests that these questions, which are focused on "distress about" sleep difficulties, should be highly correlated with self-reported sleep difficulties. In their validation study of the Insomnia Severity Index (ISI), a commonly employed self-report measure of insomnia severity, Bastien et al. (2001) found a correlation of 0.52 ($p < 0.01$) between the ISI item addressing current worry/distress about their current sleep problem and items addressing the actual severity of sleep difficulties. As such, distress about sleep difficulties is conceptualized herein as a proxy for self-reported sleep difficulties.

Antihypertensive medications

Study participants recorded all current prescription medications on a medication list. A dichotomous variable indicating antihypertensive use versus non-use was employed in statistical analyses.

Blood pressure and BMI

Electronic medical records were reviewed to obtain values for systolic blood pressure, diastolic blood pressure, weight and height for all outpatient clinic visits for the period 365 days prior to the survey and 30 days after the survey. Weight and height were used to calculate body mass index (BMI). Mean blood pressure and BMI values were used in analyses.

HTN diagnosis

Self-reported health complaints were assessed using the National Vietnam Veterans Readjustment Study (NVVRS)

Self-report Medical Questionnaire (Calhoun et al., 2009; Kulka et al., 1990). The items on this questionnaire require a dichotomous response (yes/no) to an inquiry about the presence of 22 physical symptoms and 37 chronic health conditions. Respondents are also asked to indicate if the chronic health condition has been present in the past year. Self-reported hypertension diagnosis was determined from study participants' response to the "high blood pressure or hypertension" item.

Smoking status

Respondents were asked to indicate their current smoking status (i.e., current smoker, former smoker, never smoked) on the Demographics Questionnaire. Pack years was tallied from responses to a series of follow-up questions for current and former smokers.

PTSD and depression diagnoses

PTSD and other Axis I psychiatric diagnoses were evaluated using the Structured Clinical Interview for DSM-IV-TR Axis I Disorders (SCID: First et al., 1996). SCID interviewers were trained to criteria on SCID administration using videotaped sessions, and were supervised by clinical psychologists. SCID raters achieved a mean kappa inter-rater reliability of 0.96.

PTSD symptoms

PTSD symptoms were assessed using the Davidson Trauma Scale (DTS: Davidson et al., 1997). The DTS is a brief self-report measure assessing the 17 diagnostic symptoms of PTSD as outlined in the DSM-IV. Each PTSD symptom is rated by respondents on a 5-point scale in terms of both frequency (0 = "not at all" to "every day") and severity (0 = "not at all distressing" to 4 = "extremely distressing"). The reliability and validity of the DTS has been established in OEF/OIF Veterans (McDonald et al., 2009). A cut-off value of 64 was found to have good sensitivity (0.86) and specificity (0.70) (Sijbrandij et al., 2008) and was used in our analyses to define clinically significant PTSD symptoms.

Depression symptoms

Depression symptoms were assessed using the Beck Depression Inventory-II (BDI-II: Beck et al., 1996), which is a 21-item inventory assessing depression which has been validated in both clinical and non-clinical populations. Scores on the BDI-II range from 0 to 63, with categorical ratings as follows: 0–13 (minimal depression); 14–19 (mild depression); 20–28 (moderate depression); and 29–63 (severe depression). Internal consistency and reliability of the BDI-II is well-established (Dozois & Covin, 2004). A cut-off score of 17 was found to be sensitive (93 %) and specific (88 %) against SCID-based diagnosis of MDD (Beck et al., 1996) and was used in our analyses to define clinically significant depression symptoms.

Analyses

Descriptive statistics were calculated on demographic variables, for the overall sample and then by four categories: (1) only "moderate to severe" sleep onset difficulties; (2) only "moderate to severe" sleep maintenance difficulties; (3) both "moderate to severe" onset and maintenance difficulties; and, (4) no or minimal sleep problems. Means and standard deviations were calculated for the continuous variables (age, number of tours, BMI, DTS score and BDI-II Score). Frequencies and percents were calculated for the categorical variables (gender, race, marital status, and active duty status). Statistical tests were performed to examine differences between the "no or minimal sleep problems" category versus each of the other three categories. For continuous variables, an analysis of variance (ANOVA) and overall p values were examined. For categorical variables, a Pearson Chi square statistic and p values were employed.

The cardiovascular risk variables were dichotomized as follows: current smoker versus non-smoker; pack years >4.5 versus ≤ 4.5 years; body mass index >25 versus ≤ 25; self-reported hypertension diagnosis endorsed versus not endorsed; self-report hypertension medications endorsed versus not endorsed; systolic blood pressure ≥ 120 versus <120 mmHg, diastolic blood pressure ≥ 80 versus <80 mmHg, current PTSD diagnosis-present versus absent, clinically significant PTSD symptoms indicated by DTS score >64 versus ≤ 64, current depression diagnosis-present versus absent, and clinically significant depression symptoms operationalized as a BDI-II score ≥ 17 versus <17.

Unadjusted odds ratios (and their corresponding confidence intervals) were calculated to examine associations between: (1) the various dichotomized cardiovascular risk variables and severity of sleep onset difficulties, and (2) cardiovascular risk variables and severity of sleep maintenance difficulties. Because age and race are known to influence cardiovascular risk, a Breslow Day test assessed the homogeneity of the odds ratios across the following subgroups: young (<37 years)/white; young/minority; older (≥ 37 years)/white; and older/minority.

Results

Sample description

As discussed above, analyses were conducted on a subset of participants in the MIRECC Registry database (N = 1855). Of the 1855 study participants, 149 (8.03 %) endorsed only sleep onset difficulties, 164 (8.84 %) endorsed only sleep maintenance difficulties, and 762 (41.08 %) endorsed both sleep onset and sleep maintenance difficulties. More than half of the sample (57.95 %) endorsed moderate to severe sleep difficulties of some type. The remaining 780 (42.05 %) participants endorsed either minimal sleep problems or none. Table 1 summarizes demographic, deployment, medical and psychiatric characteristics of the sample. Mean age of the participants was 37.4 years, the sample was predominantly male (79.62 %), deployed more than once (1.46 tours), and largely Veterans (94.08 %; vs. active duty). Relative to participants with none/minimal sleep problems, those having moderate to severe sleep maintenance difficulties were older ($p = 0.01$), and those having both moderate to severe sleep onset and maintenance difficulties were younger ($p = 0.04$) and reported more tours of duty ($p = 0.04$). Participants endorsing moderate to severe sleep difficulties of any kind reported more symptoms of depression ($p < 0.0001$) and PTSD ($p < 0.0001$).

Association between CVD risk factors and sleep onset difficulties

Table 2 summarizes the association between each CVD risk factor and the severity of sleep onset difficulties only. When the Breslow Day test indicated a lack of homogeneity across the following four subgroups (younger white, younger non-white, older white, and older non-white), odds ratios are reported for subgroups. Otherwise, odds ratios are reported for the sample as a whole. Relative to those with none/minimal sleep problems of any kind, those with moderate to severe sleep onset difficulties had greater odds of being a current smoker (OR 2.19, CI 1.46–3.28), having a diagnosis of PTSD (OR 5.02, CI 3.12–8.08), having clinically significant PTSD symptoms (OR 8.57, CI 5.03–14.61), having a diagnosis of depression (OR 2.80, CI 1.54–5.07), and having clinically significant depression symptoms (OR 4.41, CI 2.87–6.78). The odds for these risk factors did not differ by the combination of age and race. There was evidence, however, of age by race differences in the association between severity of sleep onset difficulties and systolic blood pressure ($p = 0.03$).

Table 1 Comparison of participants by demographic/military service characteristics and sleep difficulties

	Sample		None/minimal sleep problems N = 780	Moderate/severe sleep onset difficulties N = 149	Moderate/severe sleep maintenance difficulties N = 164	Moderate/severe sleep onset and maintenance difficulties N = 762	Overall *p* value
	N	*Mean* (*SD*)	*Mean* (*SD*)	*Mean* (*SD*)	*Mean* (*SD*)	*Mean* (*SD*)	
Age (in years)	1855	37.37 (10.09)	37.71 (10.34)	36.48 (9.94)	39.88 (10.71)*	36.65 (9.63)*	0.001
Number of tours	1805	1.46 (1.28)	1.40 (1.36)	1.47 (1.36)	1.41 (1.23)	1.53 (1.19)*	0.22
Body mass index	401	29.52 (5.06)	29.15 (5.26)	30.27 (5.27)	29.55 (5.13)	29.69 (4.89)	0.67
DTS total score	1838	41.79 (40.28)	12.79 (20.05)	39.69 (32.34)**	42.48 (32.47)**	71.91 (36.64)**	<0.0001
BDI-II total score	1854	14.42 (12.74)	5.66 (6.96)	13.09 (9.63)**	15.59 (10.65)**	23.40 (11.97)**	<0.0001
			% within group	% within group	% within group	% within group	% within group	
Males	1855		79.62	79.87	79.87	81.10	79.00	0.93
Minority race	1855		53.48	54.49	59.73	47.56	52.49	0.15
Married	1852		54.54	53.34	52.35	65.85	53.75	0.02*
Active duty	1840		5.92	6.74	9.52	3.05	5.01	0.05

SD standard deviation

* $p < .05$, ** $p < .01$

Table 2 Odds of CVD risk factors by severity of sleep onset difficulties

	Sample[a]		Statistic[b]		Group[c]	None/minimal sleep difficulties (%)	Moderate/severe sleep onset difficulties (%)
	N	%	OR	CI			
Behavioral factors							
Current smoker	918	19.72	**2.19**	(1.46–3.28)	Sample	17.53	31.08
Pack years (>4.5) current and ex-smokers	406	46.80	1.23	(0.73–2.09)	Sample	46.81	46.75
Pack years (>5.75) current smokers only	180	47.78	1.50	(0.7–3.21)	Sample	46.67	51.11
Body mass index >25	173	82.08	1.93	(0.52–7.15)	Sample	81.08	88.00
Physiological factors							
Self-reported hypertension diagnosis	801	25.09	1.52	(0.97–2.38)	Sample	23.89	31.71
Hypertension medication use	496	32.26	1.12	(0.66–1.87)	Sample	32.08	32.99
Systolic blood pressure ≥120 mmHg	287	68.29					
			4.83	(1.25–18.57)	YW	49.15	82.35
			4.22	(0.85–20.92)	YNW	56.60	84.62
			0.23	(0.04–1.19)	OW	76.74	42.86
			3.38	(0.41–27.73)	ONW	78.05	92.31
Diastolic blood pressure ≥80 mmHg	287	35.54	1.14	(0.6–2.17)	Sample	35.44	36.00
Psychiatric factors							
Current PTSD diagnosis	854	10.30	**5.02**	(3.12–8.08)	Sample	7.07	27.82
PTSD symptoms (>64 on DTS)	922	6.94	**8.57**	(5.03–14.61)	Sample	3.61	24.49
Current depression diagnosis	929	5.81	**2.80**	(1.54–5.07)	Sample	4.62	12.08
Depression symptoms (≥17 on BDI)	929	12.27	**4.41**	(2.87–6.78)	Sample	8.85	30.20

Bold values indicate statistical significance ($p < .05$)

PTSD posttraumatic stress disorder

[a] Percent within group

[b] Odds ratio calculated for subgroups when Breslow Day indicates they are not homogeneous. Otherwise, the sample odds ratio is reported

[c] *YW* younger white, *YNW* younger non-white, *OW* older white, *ONW* older non-white

Among younger whites, those with moderate/severe sleep onset difficulties had significantly greater odds of systolic blood pressure ≥120 (4.83 OR, CI 1.25–18.57) relative to younger whites with none/minimal sleep onset difficulties. The other subgroups did not show evidence of an association.

Association between CVD risk factors and sleep maintenance difficulties

Table 3 summarizes the association between each CVD risk factor and the severity of sleep maintenance difficulties only. Again, when the Breslow Day test indicated a lack of homogeneity across the following four groups (younger white, younger non-white, older white, and older non-white), odds ratios are reported for subgroups. Relative to those with none/minimal sleep maintenance difficulties, those with moderate to severe sleep maintenance difficulties had greater odds of having a diagnosis of PTSD (OR 7.55, CI 4.78–11.94) and having clinically significant PTSD symptoms (OR 10.00, CI 5.91–16.93). The odds for these risk factors did not differ by the combination of age and race. There was evidence, however, of age by race differences in the association between severity of sleep maintenance difficulties and both current depression diagnosis as well as depression symptoms. Among younger non-whites and older whites, those with moderate/severe sleep maintenance difficulties had significantly greater odds of having a diagnosis of depression (OR 8.96, CI 3.35–23.95; OR 4.16, CI 1.22–14, respectively). Moderate/severe sleep maintenance difficulties was associated with higher odds of depression symptoms across all age/race groups, but the strength of this association varied (OR 4.08–17.42).

Association between CVD risk factors and the combination of sleep onset and maintenance difficulties

Table 4 summarizes associations between each CVD risk factor and the severity of combined sleep onset and maintenance difficulties. Relative to those with none/minimal sleep problems of any kind, those endorsing both moderate to severe sleep onset and maintenance difficulties had greater odds of being a current smoker (OR 2.21, CI 1.73–2.81), having a diagnosis of PTSD (OR 19.30, CI

Table 3 Odds of CVD risk factors by severity of sleep maintenance difficulties

	Sample[a]		Statistic[b]		Group[c]	None/minimal sleep difficulties (%)	Moderate/severe sleep maintenance difficulties (%)
	N	%	OR	CI			
Behavioral factors							
Current smoker	934	18.20	1.38	(0.9–2.11)	Sample	17.53	21.34
Pack years (>4.5) current and ex-smokers	402	48.01	1.13	(0.66–1.94)	Sample	46.81	53.42
Pack years (>5.75) current smokers only	170	46.47	0.84	(0.38–1.85)	Sample	46.67	45.71
Body mass index >25	184	81.52	1.15	(0.43–3.1)	Sample	81.08	83.33
Physiological factors							
Self-reported hypertension diagnosis	815	25.15	1.39	(0.91–2.14)	Sample	23.89	31.39
Hypertension medication use	504	32.34	0.97	(0.6–1.57)	Sample	32.08	33.33
Systolic blood pressure ≥120 mmHg	311	66.56	1.15	(0.65–2.05)	Sample	65.82	68.92
Diastolic blood pressure ≥80 mmHg	311	35.37	1.01	(0.57–1.77)	Sample	35.44	35.14
Psychiatric factors							
Current PTSD diagnosis	863	11.70	**7.55**	(4.78–11.94)	Sample	7.07	35.21
PTSD symptoms (>64 on DTS)	938	7.46	**10.00**	(5.91–16.93)	Sample	3.61	25.77
Current depression diagnosis	944	5.93					
			1.77	(0.46–6.81)	YW	5.35	9.09
			8.96	(3.35–23.95)	YNW	6.52	38.46
			4.16	(1.22–14.24)	OW	2.98	11.32
			0.51	(0.06–4.08)	ONW	3.73	1.92
Depression symptoms (≥17 on BDI)	944	14.62					
			4.08	(1.68–9.91)	YW	9.63	30.30
			17.42	(6.78–44.73)	YNW	9.78	65.38
			13.50	(6.09–29.95)	OW	7.14	50.94
			4.25	(2.01–8.98)	ONW	8.71	28.85

Bold values indicate statistical significance ($p < .05$)

PTSD posttraumatic stress disorder

[a] Percent within group

[b] Odds ratio calculated for subgroups when Breslow Day indicates they are not homogeneous. Otherwise, the sample odds ratio is reported

[c] *YW* younger white, *YNW* younger non-white, *OW* older white, *ONW* older non-white

13.94–26.73), having clinically significant PTSD symptoms (OR 38.83, CI 25.88–58.26), having a diagnosis of depression (OR 11.05, CI 7.66–15.94), and having clinically significant depression symptoms (OR 21.79, CI 16.28–29.15). The odds for these risk factors did not differ by the combination of age and race. There was evidence, however, of age by race differences in the association between severity of both sleep maintenance and onset difficulties with hypertension ($p = 0.03$) and elevated systolic blood pressure ($p = 0.03$). Among younger whites, those with moderate/severe sleep onset and maintenance difficulties were more likely to endorse a hypertension diagnosis (OR 3.06, CI 1.53–6.10) and have elevated systolic blood pressure readings (OR 3.10, CI 1.59–6.07). Moderate/severe sleep onset and maintenance difficulties were also associated with greater odds of endorsing a hypertension diagnosis among younger non-whites (OR 2.36, CI 1.36–4.11) and older whites (OR 2.10, CI 1.24–3.56).

Discussion

In the current study, we sought to examine cross-sectional relationships between sleep difficulties and behavioral, physiological, and psychiatric risk factors for CVD in a relatively young sample of current and former military service members. Our hypotheses about these relationships were partially supported. Self-reported sleep difficulties were associated with increased odds of being a current smoker in the sample as a whole, whereas odds of elevated blood pressure, self-reported HTN diagnosis, and psychiatric symptoms/diagnoses depended upon one's subgroup membership as defined by an interaction of age and race. Other known CVD risk factors, including BMI and diastolic blood pressure, were not associated with self-reported sleep difficulties in this sample.

Although a large body of prior research has demonstrated that older age and African-American race are risk

Table 4 Odds of CVD risk factors by severity of combined sleep onset and maintenance difficulties

	Sample[a]		Statistic[b]		Group[c]	None/minimal sleep difficulties (%)	Moderate/severe onset andmaintenance sleep difficulties (%)
	N	%	OR	CI			
Behavioral factors							
Current smoker	1526	24.77	**2.21**	(1.73–2.81)	Sample	17.53	32.14
Pack years (>4.5) current and ex-smokers	732	49.45	1.29	(0.95–1.76)	Sample	46.81	51.61
Pack years (>5.75) current smokers only	376	50.27	1.21	(0.75–1.95)	Sample	46.67	52.28
Body mass index >25	340	82.94	1.31	(0.74–2.31)	Sample	81.08	84.38
Physiological factors							
Self-reported hypertension diagnosis	1319	28.58					
			3.06	(1.53–6.1)	YW	7.19	19.15
			2.36	(1.36–4.11)	YNW	15.43	30.14
			2.10	(1.24–3.56)	OW	25.53	41.88
			1.11	(0.74–1.64)	ONW	42.79	45.26
Hypertension medication use	944	29.77	0.93	(0.69–1.25)	Sample	32.08	28.07
Systolic blood pressure ≥120 mmHg	569	70.47					
			3.10	(1.59–6.07)	YW	49.15	75.00
			1.82	(0.85–3.9)	YNW	56.60	70.31
			0.91	(0.37–2.23)	OW	76.74	75.00
			0.80	(0.4–1.6)	ONW	78.05	73.91
Diastolic blood pressure ≥80 mmHg	569	37.96	1.25	(0.88–1.78)	Sample	35.44	39.76
Psychiatric factors							
Current PTSD diagnosis	1379	32.20	**19.30**	(13.94–26.73)	Sample	7.07	59.73
PTSD symptoms (>64 on DTS)	1528	31.02	**38.83**	(25.88–58.26)	Sample	3.61	59.23
Current depression diagnosis	1542	19.65	**11.05**	(7.66–15.94)	Sample	4.62	35.04
Depression symptoms (≥17 on BDI)	1541	38.03	**21.79**	(16.28–29.15)	Sample	8.85	67.94

Bold values indicate statistical significance ($p < .05$)

PTSD posttraumatic stress disorder

[a] Percent within group

[b] Odds ratio calculated for subgroups when Breslow Day indicates they are not homogeneous. Otherwise, the sample odds ratio is reported

[c] *YW* younger white, *YNW* younger non-white, *OW* older white, *ONW* older non-white

factors for hypertension in US adults, the potential for interaction between these risk factors and sleep remains a generally unexplored topic. Our findings point to the possibility that younger service members may be at relatively greater sleep-related risk for CVD. In addition, our findings suggest that although older non-whites were found to have a higher occurrence of hypertension diagnosis, they may have relatively lower sleep-related risk for CVD. When examined in the context of sleep difficulties, the established relationships between blood pressure and older age and minority status were not present, and certain subgroups had greater odds of hypertension and elevated systolic blood pressure. Specifically, combined sleep onset and maintenance difficulties were associated with self-reported HTN diagnosis and elevated systolic blood pressure in younger whites. Sleep onset difficulties only were also associated with elevated systolic blood pressure in younger whites.

We were unable to find prior research showing these age-by-race associations between severity of sleep difficulties and blood pressure, but did identify a few studies examining relationships between severities of sleep difficulties and each of age and race independently. Consistent with our findings, short sleep duration (≤5 h) was associated with an increased incidence of hypertension in younger women (<60 years) relative to older women (≥60 years) participating in the Nurses' Health Study (Gangwisch et al., 2013). In a recent meta-analysis on sleep

duration and hypertension, the authors reported a stronger relationship between sleep and hypertension in adults under the age of 60 (OR 1.33, $p = 0.17$) relative to those over the age of 60 (OR 0.99, $p = 0.91$) (Guo et al., 2013). In contrast with our findings, however, a prior study examining blood pressure and sleep difficulties in middle-aged African-Americans and Caucasians did not reveal race-related differences in sleep and blood pressure associations (Matthews et al., 2008).

Consistent with research in civilian populations, we found in this sample of US service members that current smoker status was associated with both sleep onset and the combination of sleep onset and maintenance difficulties. Those with moderate to severe sleep difficulties were about twice as likely to be a current smoker. Mechanisms for associations between subjective reports of disturbed sleep and smoking remain largely unexplored. Notable exceptions include findings that women who are chronic heavy-smokers are more likely to experience insomnia in later life (Brook et al., 2012), and that sleep difficulties following smoking cessation increase the likelihood of relapse (Okun et al., 2011). Although cross-sectional relationships between sleep and smoking have been a secondary focus of several studies, additional longitudinal research is needed to better understand the how these CVD risk factors may interact to increase risk.

Our hypothesis that sleep difficulties would be associated with BMI was not supported, and this is surprising in light of their established relationship in the empirical literature. Our finding could be explained by the reduced power of the smaller sample size for body mass index. Our finding that sleep difficulties are associated with both PTSD and depression is unsurprising because sleep difficulties are a symptom of both disorders. However, we assert that both sleep difficulties and psychiatric conditions (e.g., PTSD and depression) are important CVD risk factors in need of greater attention in both research and clinical practice. As such, we included these psychiatric outcomes in our analyses to underscore their relative contribution to cardiovascular risk profiles. In fact, with the abundance of research emerging on both sleep and psychiatric morbidities as risk factors for CVD, future research may reveal a synergistic effect for these combined conditions. Our finding of an age by race interaction for associations between depression symptoms/diagnosis and sleep maintenance difficulties is unclear. Data from the Behavioral Risk Factor Surveillance System (BRFSS) suggests that persons 45–64 years of age and non-whites are at highest risk of depression (CDC, 2010). However, little research has examined demographic factors as they relate to sleep and depression associations.

Our findings should be viewed in light of several limitations. First, since clinic-based blood pressure readings were utilized, the elevated systolic blood pressure readings we found using clinic-based assessment could reflect white-coat hypertension in a subset of study participants. However, the consistency between the objective and self-reported blood pressure/hypertension findings argues against this possibility. Moreover, elevations in systolic blood pressure were only found in certain subgroups, and there is no reason to suspect that only these subgroups experience white-coat hypertension. To lessen concerns about missing data for BMI and blood pressure readings, we conducted sensitivity analyses to determine if participants with missing data differed from those with complete data on these variables. We found that those missing BMI data did not differ on age, gender, race, marital status or number of tours served. Those with missing blood pressure readings were slightly older ($p = 0.03$), but were not different in terms of gender, race, marital status, or number of tours served.

The use of self-reported hypertension diagnosis may also be a limitation. Some findings suggest that self-reported hypertension diagnosis should not be used for epidemiological research (Dave et al., 2013), while others found that the reliability of self-reported hypertension diagnosis is acceptable (Okura et al., 2004; Muggah et al., 2013). It should also be noted that in the absence of data on other known risk factors which were unavailable for our sample (physical activity, diet and genetic risk factors), the possibility that sleep difficulties convey differential risks based on age and race remains speculative. However, our findings suggest that future research employing longitudinal design is needed to examine this possibility. Finally, it should be stated that the items we used to examine sleep difficulties were focused on "distress about" sleep difficulties. As discussed above, these items should be highly correlated with self-reported sleep difficulties. As such, we utilized them as proxies for perceived sleep difficulties. However, future research could examine the possibility that distress and worry about sleep difficulties could contribute to CVD risk independent of any risks conveyed from perceived sleep impairment.

Strengths of our study include the use of mental health diagnoses based on clinician-administered structured clinical interviews rather than self-report measures, and a relatively large sample size. In addition, prior research has rarely examined and reported findings for behavioral, physiological and psychiatric risk factors for CVD within the same sample. Finally, our findings are among the first to report associations between sleep and risk factors for CVD in the US service members of recent military conflicts.

Even when the qualifying issues summarized above are considered, our findings underscore the importance of considering sleep difficulties as a risk factor for CVD in a population that is known to be at increased risk for this

condition. Since sleep difficulties are associated with several CVD risk factors in younger US military service members, improving sleep in this population may reduce the progression of the disease and avert the increased incidence of CVD seen in older Veterans. Findings of a recent pilot study lend support to this possibility. Following a successful behavioral intervention to increase sleep duration, pre-hypertensive and Stage 1 hypertensive adults sleeping <7 h per night experienced a significant decrease in systolic blood pressure (Haack et al., 2013). Our findings support the need for future research to determine if improved sleep results in improvements in the physiological markers of CVD, and if intervening on sleep impacts behavioral and psychiatric risk factors for CVD as well.

Acknowledgments Christi S. Ulmer was supported by a Veterans Affairs Research Career Development Award (CDA 09-218) while preparing this manuscript. This project was supported by the Mid-Atlantic Mental Illness Research, Education and Clinical Center (VISN 6 MIRECC) of the Department of Veterans Affairs Office of Mental Health Services, the VA Mid-Atlantic Healthcare Network (VISN 6), the Durham, NC Veterans Affairs Medical Center, and the Department of Veterans Affairs Office of Research and Development. The views expressed are those of the authors and do not necessarily represent the views of the Department of Veterans Affairs or any of the institutions with which the authors are affiliated. The Mid-Atlantic Mental Illness Research, Education, and Clinical Center Workgroup for this manuscript includes: Patrick S. Calhoun, Eric B. Elbogen, John A. Fairbank, Jeffrey M. Hoerle, Christine E. Marx, Scott D. Moore, Rajendra A. Morey, Kristy A. Straits-Tröster, Larry A. Tupler, Richard D. Weiner, and H. Ryan Wagner from the Durham (NC) VA Medical Center; Marinell Miller-Mumford from the Hampton (VA) VA Medical Center; Antony Fernandez, Scott D. McDonald, and Treven C. Pickett from the Richmond (VA) VA Medical Center; Robin A. Hurley, Katherine H. Taber, and Ruth E. Yoash-Gantz from the Salisbury (NC) VA Medical Center; and Gregory McCarthy, from Yale University.

Conflict of interest Christi S. Ulmer, Hayden B. Bosworth, Anne Germain, Jennifer Lindquist, Maren Olsen, Mira Brancu, the VA Mid-Atlantic Mental Illness Research Education and Clinical Center Registry Workgroup, and Jean C. Beckham all declare that they have no conflicts of interest.

Human and Animal Rights and Informed Consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants included in the study.

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