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Sleepy and grumpy go hand in hand for US Navy Sailors

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Abstract

Study Objectives: The study explores how sleep, sleep-related practices, and behaviors, in addition to various demographic and occupational characteristics, are related to overall mood of US Navy sailors when they are underway.

Methods: Longitudinal assessment of US Navy sailors performing their underway duties (*N* = 873, 79.2% males, median age 25 years). Participants completed standardized questionnaires, wore wrist-worn actigraphs, and completed daily activity logs.

Results: Sailors who reported worse profile of mood states (POMS) total mood disturbance scores had shorter sleep duration, worse sleep quality, and more episodes of split sleep. The group with worse mood also reported more symptoms of excessive daytime sleepiness as well as more symptoms of insomnia. In addition to sleep results, sailors with worse mood also tended to be younger, more likely to use nicotine and tobacco products, and less likely to have an exercise routine when compared to sailors with better POMS scores. Finally, the group with worse POMS scores included more enlisted personnel, tended to work more hours per day, and were more likely to stand watch—especially on rotating watch schedules.

Conclusions: The results found significant associations between the sleep practices and mood of sailors aboard US Navy ships. Numerous other demographic and occupational factors were also strongly associated with mood. This paper is part of the Sleep and Circadian Rhythms: Management of Fatigue in Occupational Settings Collection.

This paper is part of the Sleep and Circadian Health in the Justice System Collection.

Key words: insufficient sleep; crew endurance; sailor well-being; psychological mood and sleep

Statement of Significance

Insufficient sleep, despite its well-known consequences on performance, mood, and mental health, continues to be prevalent in military populations. In this paper, we explore how sleep is related to mood, health behaviors (both physical and mental), and the well-being of members of the US Navy.

Introduction

Sleep plays a vital role in all aspects of health—to include mental and emotional well-being. Several studies investigating numerous populations and contexts show the relationship between sleep and mental health, e.g. mood [1], quality of life and relapse in bipolar disorder [2], distress symptoms [3], and depression [4]. Most troubling is the known associations between sleep disturbances and suicidality [5–8].

Almost half of the members of the US Navy and US Marine Corps are 25 years old or younger. Numerous studies have identified relationships between sleep and well-being in young adults. Regularity in the timing of sleep is an important predictor of psychological well-being in young adults [9]. In a recent 6-month study comparing sleep on school days, weekends, and holidays, sleep regularity on school days was associated with lower depressive symptoms. Additionally, those students with more irregular sleep on weekends presented worse mental health outcomes [10]. Another study in 2017 by Bei et al. looked at the sleep of 146 students during a vacation period away from the more structured school schedule [1]. Depressive symptoms and anxiety were associated with variability in bedtimes and sleep onset latency.

However, the impact of sleep on well-being is not limited to young adults. A study of 441 adults found day-to-day variability in sleep duration to be a better predictor of lower subjective well-being than sleep duration, sleep onset latency, and time awake after sleep onset [3]. Conversely, improvements in sleep quantity, quality, and consistency can all have positive outcomes for patients with depression, bipolar disorder, and anxiety [2]. In military settings, rotating shift schedules, especially those that are non-circadian and run counter to the established biological rhythms, are known to result in irregular sleep patterns [11, 12].

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Despite known consequences on mood and mental health, insufficient sleep, sleepiness, and fatigue are prevalent in military populations. In a longitudinal study of 669 US Navy watchstanders, 68% slept less than 7 hours per day [13]. Nearly a third (32%) of sailors deployed on a US Navy aircraft carrier reported excessive daytime sleepiness (EDS) and 28% reported elevated fatigue levels [14]. Healthy sleep patterns—comprised of both consistent bedtime and adequate duration—are especially difficult for military members to maintain. These individuals are often required to work on 24/7 schedules that fluctuate depending on operational needs. Additionally, their sleep is often fragmented due to operational interruptions (e.g. combat operations, training drills, and environmental conditions such as noise). A large percentage of these active-duty service members are quite young, ranging from 18 to 22 years of age, and requiring at least 9 hours of sleep per night on a regular basis for optimal health [15]. Finally, members of the military are often required to mobilize across the globe, spanning numerous time zones, resulting in circadian disruption and poor sleep patterns.

The purpose of this project was to examine the relationship between sleep and mood of crew members onboard US Navy ships. In addition, we looked at demographic and occupational characteristics of study participants. A series of eight separate data collection events occurred over a 7-year period, the results of which were combined into one large dataset. Sleep quality, sleep duration, and sleep consistency—in addition to participant demographic and occupational characteristics—were all examined as potential correlates of sailors' mood. Given the importance of proper sleep habits, the relatively poor sleep observed among military populations, and the potentially grave consequences, it is important to understand the relationship between sleep and mood, especially given the known relationship between mood and mental health.

Materials and Methods

Participants

United States Navy sailors (N = 1086) assigned to one of the eight surface ships (one Nimitz-class aircraft carrier, one Ticonderoga-class cruiser, five Arleigh Burke-class destroyers, and one Whidbey Island-class amphibious ship) were recruited and enrolled in ongoing studies of work and rest patterns of US Navy personnel. Data were collected at different time periods of approximately 1 to 3 weeks each between 2014 and 2020. Three of the ships were conducting underway training exercises and five of the ships were operationally deployed. All sailors onboard during the study periods were eligible to participate. Study procedures were approved by the Institutional Review Board of the Naval Postgraduate School and participants provided written informed consent.

Based on their principal work schedule, sailors were classified into one of two occupational groups, watchstanders and non-watchstanders. "Watchstanders" included sailors who "stood watch," i.e. a period of time during which a sailor is assigned specific, detailed responsibilities on a recurring basis [16]. While standing watch, these sailors are not allowed to leave their posts. The watchstander group included sailors working various schedules with 70.1% on fixed schedules (i.e. standing watch at the same time each day) and 29.9% on rotating schedules (i.e. standing watch at different times every day).

"Non-watchstanders" included sailors who did not stand watch. These sailors had normal workday hours or were shift workers but their shifts were more flexible, i.e. they included more self-paced tasks in which sailors may be permitted to take brief rest periods if needed. Regardless of their status, all sailors while underway were responsible for carrying out various other duties, to include attending meetings, training, drills, or other work and operational commitments.

Equipment and instruments

Actigraphy.

Following existing recommendations [17, 18], sleep periods were identified by wrist-worn actigraphy via Motionlogger Watch (Ambulatory Monitoring, Inc. [AMI]; Ardsley, New York) or the Spectrum watch (Philips-Respironics; Bend, Oregon) and activity logs. Within each rest interval, actigraphically assessed sleep was calculated automatically. Actigraphy data for both devices were collected in 1-minute epochs. Motionlogger data (collected in the Zero-Crossing Mode) were scored using Action W version 2.7.2155 software using the Cole-Kripke algorithm with rescoring rules. The criterion for sleep and wake episodes was five minutes; the sleep latency criterion was no more than 1 minute awake in a 20-minute period (all default values for this software). Spectrum data were scored using Actiware software version 6.0.0 (Phillips Respironics; Bend, Oregon) using the medium sensitivity threshold (40 counts per epoch), with 10 immobile minutes as the criterion for sleep onset and sleep end (all default values for this software). Previous research has shown that Motionlogger data analyzed with Cole-Kripke and Spectrum data analyzed with medium sensitivity parameters assess total sleep time for an approximately 8-hour night sleep episode with 3-minute precision [19].

Questionnaires.

A pre-study questionnaire included demographic information (age, sex, and rank), use of caffeinated beverages, use of nicotine products, having an exercise routine, and use of prescribed or over-the-counter medications. An end-of-study questionnaire asked participants to indicate whether they stood watch during the underway and the type of watchstanding schedule used. Also, the end-of-study questionnaire included four standardized psychometric tools described below. Depending on the duration of the data collection, each tool asked questions pertaining to participant experiences over the most recent 1 to 2-week period.

The 8-item self-rated Epworth Sleepiness Scale (ESS) was used to assess average daytime sleepiness [20]. The items included in the ESS represent eight situations commonly encountered in daily life. Using a 4-point Likert scale (0 to 3), participants indicate their chance of dozing off or falling asleep in these eight situations with 0 being "would never doze," 1 being "slight chance of dozing," 2 being "moderate chance of dozing," and 3 denotes a "high chance of dozing." The total ESS score ranges from 0 to 24. A score greater than 10 reflects daytime sleepiness above normal [20, 21]. The questionnaire has a high level of internal consistency as measured by Cronbach's alpha, which ranges from 0.73 to 0.88, and a test–retest reliability of 0.82 [21]. The operational utility of the ESS lies in its ability to assess average sleepiness in daily life [22] and to identify individuals who are at higher risk of psychomotor performance impairment [23].

The insomnia severity index (ISI) is a 7-item self-report measure that was used to assess the perceived severity of insomnia [24, 25]. Each item uses a 5-point Likert-type scale from 0 to 4, with higher numbers corresponding to greater sleep problems. The items sum to produce a total score (range 0–28). The ISI has an internal consistency alpha coefficient of 0.74 and has shown convergent validity with other sleep measures (r = 0.55–0.67), and sleep diaries (r ranges from 0.32 to 0.91). An ISI score ≥ 15 denotes symptoms of clinically significant insomnia [24].

The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality [26]. From the 24 PSQI items, 19 are self-rated and five items are rated by the bedpartner or the roommate. The self-rated questions yield seven component scores (sleep quality, sleep latency, duration, sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction) rated from 0 (better) to 3 (worse). The Global score, ranging from 0 (better) to 21 (worse), is the summation of the component scores. Individuals with a PSQI total score ≤ 5 are characterized as good sleepers, whereas scores > 5 are associated with poor sleep quality. The PSQI has a sensitivity of 89.6% and a specificity of 86.5% (κ = 0.75, p < 0.001) in nonmilitary populations, and an internal consistency α = 0.83 [26]. Even though the original version of PSQI referred to sleep quality during the previous month, the ecological validity of the tool, i.e. participants' accuracy in recalling sleep quality has been demonstrated for various reporting periods from 3 days to 1 month [27].

The profile of mood states (POMS) scale was used to assess mood using six subscales [28]. The POMS is a standardized, 65-item inventory originally developed to assess mood state in psychiatric populations. For each item, participants are instructed to "circle the number that best describes how you have been feeling during the past week, including today" with five potential responses ranging from "Not at all" [1] to "Extremely" [5]. The responses to the items are used to calculate total scores on six subscales: Anger-Hostility (12 items; range 0–48), Confusion-Bewilderment (seven items; range 0–28), Depression (15 items; range 0–60), Fatigue (7 items; range 0–28), Tension-Anxiety (9 items; range 0–36) and Vigor-Activity (8 items; range 0–32). Lower scores on the first five subscales correspond to better perceived mood, with higher scores corresponding to worse perceived mood. On the Vigor-Activity subscale, a lower score corresponds to better mood. A total mood disturbance (TMD) score is then derived by adding the first five subscales and subtracting the score for Vigor with higher TMD scores indicating worse mood (TMD ranges from −32 to 200). Normalized TMD scores are based on adult norms [29].

Study design and procedures

The data used for this paper were collected from eight 7 to 18-day underway field assessments on US Navy ships using a prospective naturalistic design. Sailors were assigned to the same schedule for at least 3 days prior to commencement of the study and these schedules were maintained throughout the study period. All sailors were asked to complete the pre-study questionnaire, wear a wrist-worn actigraph, and fill out a daily activity log during the data collection period. At the end of the data collection period, sailors were asked to complete the post-study questionnaire.

Analytical approach

Initially, 1086 sailors from eight ships volunteered to participate in the studies (Figure 1). Sailors using medications known to affect sleep and/or mood (i.e. sleeping aids, anti-inflammatory drugs, and anti-depressants) were excluded from further analysis (n = 28). Participants with missing POMS data (n = 105) or missing watchstanding status (n = 80) were also excluded. Consequently, the analysis was based on 873 sailors of whom 754 had actigraphy data while 119 had only questionnaire data. A consort diagram is shown in Figure 1.

Sleep analysis was based on daily (24-hour) sleep duration (to include naps) and on the number of sleep episodes per day. The metric "average number of sleep episodes/day" is calculated as the ratio of the number of sleep episodes during the data collection period divided by the number of data collection days. Initially, we calculated the average number of sleep episodes per day for each participant. Next, we calculated the grand average number of sleep episodes per day for those sailors who napped during the data collection period. Sleep episodes, which were recorded in sleep logs were used to impute missing actigraphic data and accounted for 1.5% of all sleep episodes. Imputation was applied

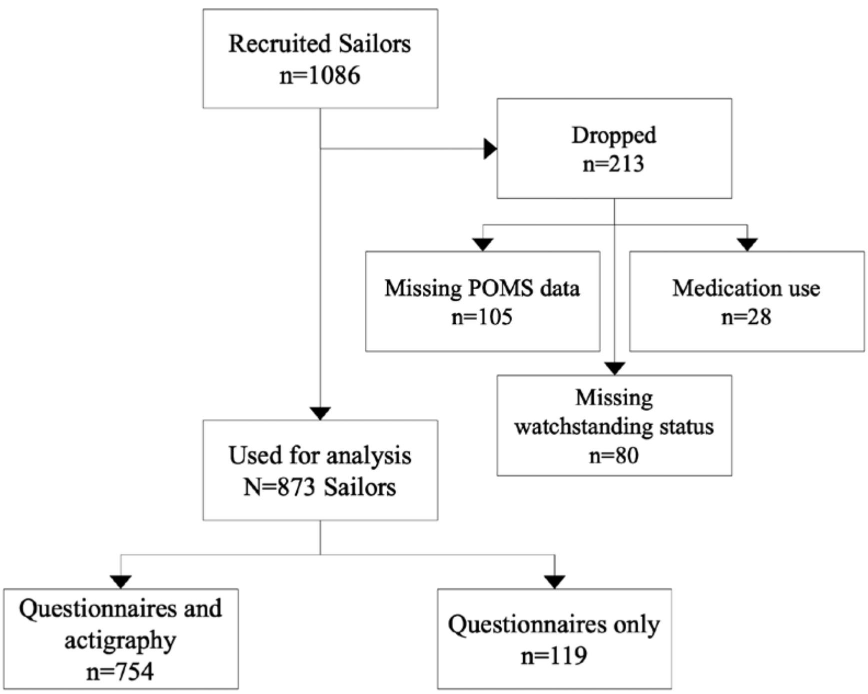

Figure 1. Consort diagram.

to sleep data only when: (1) there was a gap in actigraphy data within which the activity log showed a sleep interval, and (2) the pattern of actigraphy data, assisted by the activity logs, was such to assure confidence in the interpolation of the sleep interval. Sleep metrics were aggregated to get an average score for each individual over the entire study period.

Statistical analysis was conducted using JMP statistical software (JMP Pro 17; SAS Institute; Cary, NC). First, all variables underwent descriptive statistical analysis to identify anomalous entries and to describe the study sample in terms of demographic characteristics, sailor behaviors, and well-being. Next, we assessed the explanatory variables of the POMS scores using general linear model analysis. These variables included age nested within occupational group, sex, occupational group (officer, enlisted), watchstanding status, watchstanding schedule type (fixed, rotating) nested within watchstanding status, and daily sleep duration. Results were adjusted for individual ships. We calculated the first (best) and fourth (worst) quartiles based on sailors' POMS TMD scores. We compared these two groups to determine differences in dependent variables between the two TMD groups.

Data normality was assessed with the Shapiro–Wilk W test. Summary data were reported as mean ± standard deviation (M ± SD) or median (interquartile range) [MD (IQR)] as appropriate. An alpha level of 0.05 was used to determine statistical significance. Post hoc statistical significance was assessed using the Benjamini–Hochberg False Discovery Rate (BH-FDR) controlling procedure with $q = 0.20$ [30].

The *t*-test for groups with unequal variances, the Wilcoxon rank sum test, and Fisher's exact test were used for pairwise comparisons of continuous and categorical variables between independent samples as appropriate. The magnitude of statistically significant differences was assessed with three effect size metrics, i.e. non-parametric r metric, relative risk with a 95% confidence interval, and Hedge's g. Cohen [31, 32] considered effect sizes of 0.20 to be small, 0.50 as moderate, and effect sizes of 0.80 as large. The 1-sided binomial test was used to compare POMS scores with adult norms. Correlations were assessed with Spearman's *rho*.

Results

Sailors' characteristics

As shown in Table 1, participants had a median age of 25 (IQR = 8, minimum = 18, maximum = 59) years, most of them were male (691, 79.2%), and in the enlisted ranks (759, 86.9%). In terms of demographic characteristics, the study sample did not differ substantively from the population of sailors in the US Navy [33]. Most sailors were watchstanders (629, 72.1%) where 375 (43.0%) worked on fixed watch schedules, 172 (19.7%) worked on rotating watch schedules, and 82 (9.39%) sailors worked atypical watch schedules (under instruction, shifting between watch schedules, etc.).

Caffeinated beverage use was highly prevalent (747, 85.7%), and approximately a third of participants used nicotine/tobacco products (290, 33.3%). In total, 574 (65.8%) sailors reported having an exercise routine. Of note, 108 (12.4%) sailors reported drinking caffeinated beverages and using nicotine products but not exercising. Sailors spent a median of 11.7 hours per day (IQR = 3.11) working on their duties.

As assessed by actigraphy, participants slept an average of 6.57 ± 0.98 hours daily (ranging from 3.30 to 9.51 hours), 502 (66.6%) slept less than 7 hours per day, and 227 (30.1%) slept less than 6 hours per day. In total, 639 participants (84.8%) reported at least one nap during the data collection period. The fact that these sailors had a median number of 1.43 sleep episodes per day (IQR = 0.528) suggests that napping occurred approximately once every 2 days with approximately 10% of sailors napping every day.

In terms of average daytime sleepiness, the median ESS score was 10 (IQR = 7) and 384 (44.1%) sailors had symptoms of EDS (ESS score > 10). The median ISI score was 11 (IQR = 8) and 223 (25.6%) sailors had symptoms of clinically significant insomnia (an ISI score ≥ 15). The median PSQI Global score was 8 (IQR = 4) and 679 (78.6%) of the participants were classified as "poor sleepers" (PSQI score > 5). Detailed descriptive results of the study variables are shown in Table 1.

Based on their POMS scores, sailors were classified as to whether they were below or above the median (50th percentile) of adult norms. Analysis showed that the study sample of sailors differed from the adult norms in five of the six subscales and the TMD scale at a statistically significant level (one-sided binomial test, all $p < 0.001$). As shown in Figure 2, 83.7% of our participants had a score worse than the 50th percentile of adult norms in vigor-activity, followed by confusion-bewilderment (62.0%), anger-hostility (61.9%), fatigue (61.9%), and tension-anxiety (55.1%). In total, 69.4% of sailors had a TMD score worse than 50th percent of adult norms. Of note, sailor depression did not differ from adult norms ($p = 0.088$).

Explanatory variables of POMS scores

Next, we assessed the explanatory variables for the POMS scores. Age and daily sleep duration were not correlated (Spearman's rho = 0.001, $p = 0.954$). As shown in Table 2, the models for all POMS scales were statistically significant. Adjusted for ship, our results showed several interesting patterns. Age was a statistically significant explanatory variable for POMS TMD and four subscales (tension-anxiety, depression, anger-hostility, and confusion-bewilderment), followed by watchstanding schedule type (associated with TMD, tension-anxiety, depression, anger-hostility, fatigue, and confusion-bewilderment), daily sleep duration (associated with TMD, anger-hostility, fatigue, and confusion-bewilderment), and whether standing watch (associated with TMD and fatigue). Specifically, being older, sleeping more, not standing watch, and (if standing watch) working on a fixed watch schedule were factors associated with better mood scores. In contrast, sailors who were younger, slept less, and stood watch (especially on rotating watch schedules) had worse POMS scores. Of note, sex and occupational group (whether a sailor was enlisted or officer), were not associated with POMS TMD or any of the POMS subscales.

Differences between POMS TMD groups

Next, we grouped sailors based on their POMS TMD scores and assessed differences between the first (best) and fourth (worst) quartile. The scores used for this classification scheme were POMS TMD ≤ 12 for the first quartile and ≥ 60 for the fourth quartile. The POMS TMD scores can range from −32 to 200 with higher scores indicative of worse mood. The TMD cutoff score of 12 is equivalent to the 48th percentile in the adult norms and a score of 60 is equivalent to the 63rd percentile. The POMS TMD scores in our study sample ranged from −23 (38th percentile) to 182 (above the 80th percentile).

As shown in Table 1, substantive differences existed between the two mood groups. The fourth quartile group was 3 years younger on average compared to the first quartile group. Also, the fourth quartile group included more enlisted personnel, more sailors who used nicotine/tobacco products, and more

Table 1. Pairwise Comparisons Between POMS TMD First and Fourth Quartile Groups

Study variables	Entire sample (N = 873)	First quartile of POMS TMD scores (≤12) (*n* = 222)	Fourth quartile of POMS TMD scores (≥60) (*n* = 219)	Unadjusted P-value	Effect size
Age in years, MD (IQR)	25 (8)	27 (9)	24 (6)	<0.001[a,d]	0.186[e]
Males, # (%)	691 (79.2%)	178 (80.2%)	168 (76.7%)	0.418[b]	—
Enlisted, # (%)	759 (86.9%)	188 (84.7%)	203 (92.7%)	0.010[b,d]	1.10 (1.02–1.17)[f]
Watchstander, # (%)	629 (72.1%)	137 (61.7%)	171 (78.1%)	<0.001[b,d]	1.26 (1.17–1.43)[f]
Fixed	375 (43.0%)	88 (39.6%)	88 (40.2%)	—	—
Rotating	172 (19.7%)	32 (14.4%)	61 (27.9%)	—	—
Atypical	82 (9.39%)	17 (7.66%)	22 (10.1%)	—	—
Sailor behaviors, # (%)					
Drink caffeinated beverages	747 (85.7%)	193 (87.3%)	189 (86.7%)	0.888[a]	—
Use nicotine/tobacco product	290 (33.3%)	66 (29.9%)	90 (41.1%)	0.017[b,d]	1.38 (1.06–1.78)[f]
Do not exercise	298 (34.2%)	54 (24.4%)	91 (41.6%)	<0.001[b,d]	1.70 (1.29–2.25)[f]
All the above	108 (12.4%)	17 (7.69%)	39 (17.8%)	0.002[b,d]	2.32 (1.35–3.97)[f]
Work hours/day, MD (IQR)	11.7 (3.11)	11.1 (3.62)	12.1 (2.35)	<0.001[a,d]	0.217[e]
Sleep (actigraphy) [Note 1]					
Daily sleep duration, M ± SD	6.57 ± 0.984	6.72 ± 0.974	6.53 ± 0.987	0.074[a,d]	0.194[g]
Sailors sleeping < 7hrs, # (%)	502 (66.6%)	121 (61.7%)	129 (69.0%)	0.163[b,d]	1.12 (0.97–1.29)[f]
Sailors sleeping < 6hrs, # (%)	227 (30.1%)	49 (25.0%)	59 (31.6%)	0.173[b,d]	1.26 (0.92–1.74)[f]
Participants with > 1 sleep episodes/day, # (%)	639 (84.8%)	149 (76.0%)	166 (88.8%)	0.001[b,d]	1.17 (1.06–1.28)[f]
Sleep episodes/day, MD (IQR) [Note 2]	1.43 (0.528)	1.36 (0.467)	1.52 (0.629)	0.001[b,d]	0.181[e]
Participants with > 1.2 sleep episodes/day, # (%)	523 (69.4%)	115 (58.7%)	143 (76.5%)	<0.001[b,d]	1.30 (1.13–1.50)[f]
ESS score, MD (IQR)	10 (7)	7 (5.25)	13 (7)	<0.001[a,d]	0.442[e]
EDS (ESS score > 10), # (%)	384 (44.1%)	47 (21.2%)	139 (63.5%)	<0.001[b,d]	3.00 (2.28–3.94)[f]
ISI score, MD (IQR)	11 (8)	7 (6)	15 (7)	<0.001[a,d]	0.623[e]
ISI score ≥ 15, # (%)	223 (25.6%)	18 (8.18%)	120 (55.3%)	<0.001[b,d]	6.76 (4.27–10.7)[f]
ISI score ≥ 15 and ESS > 10, # (%)	148 (17.0%)	6 (2.72%)	92 (42.2%)	<0.001[b,d]	15.5 (6.95–34.8)[f]
PSQI global score, MD (IQR)	8 (4)	6 (3)	10 (5)	<0.001[a,d]	0.477[e]
Poor sleepers, # (%)	679 (78.6%)	135 (61.4%)	202 (93.1%)	<0.001[b,d]	1.52 (1.36–1.70)[f]
POMS scores, MD (IQR)					
Total mood disturbance	32 (48)	1 (11)	84 (30)	<0.001[a,d]	0.833[e]
Tension-anxiety	8 (9)	4 (3)	16 (5)	<0.001[a,d]	0.865[e]
Depression	7 (14)	1 (2)	25 (15)	<0.001[a,d]	0.868[e]
Anger-hostility	10 (14)	3 (4)	24 (11)	<0.001[a,d]	0.855[e]
Vigor-activity	12 (8)	15 (9)	9 (8)	<0.001[a,d]	0.440[e]
Fatigue	10 (10)	3 (5)	17 (7)	<0.001[a,d]	0.845[e]
Confusion-bewilderment	7 (7)	3 (3)	13 (5)	<0.001[a,d]	0.848[e]

Calculated over 754 Sailors with actigraphy data. Calculated only for Sailors with an average number of sleep episodes/day > 1.
[a]Wilcoxon rank sums test.
[b]McNemar's test.
[c]t-test assuming unequal variances.
[d]Statistically significant based on the BH-FDR controlling procedure.
[e]Non-parametric effect size r.
[f]Relative risk with a 95% confidence interval.
[g]Hedge's g.

sailors who did not exercise. Of note, sailors who consumed caffeinated beverages, used nicotine products, but did not exercise were 132% more likely to be included in the fourth quartile group. More watchstanders were in the fourth quartile group, and compared to watchstanders in fixed schedules, twice as many watchstanders who worked in a rotating schedule were included in the fourth quartile group. Sailors in the fourth quartile also worked on average one hour per day more than sailors in the first quartile group.

In terms of sleep, the fourth quartile group had a shorter daily sleep duration. Also, split sleep was more pronounced in the fourth quartile group as shown by (1) the percentage of nappers

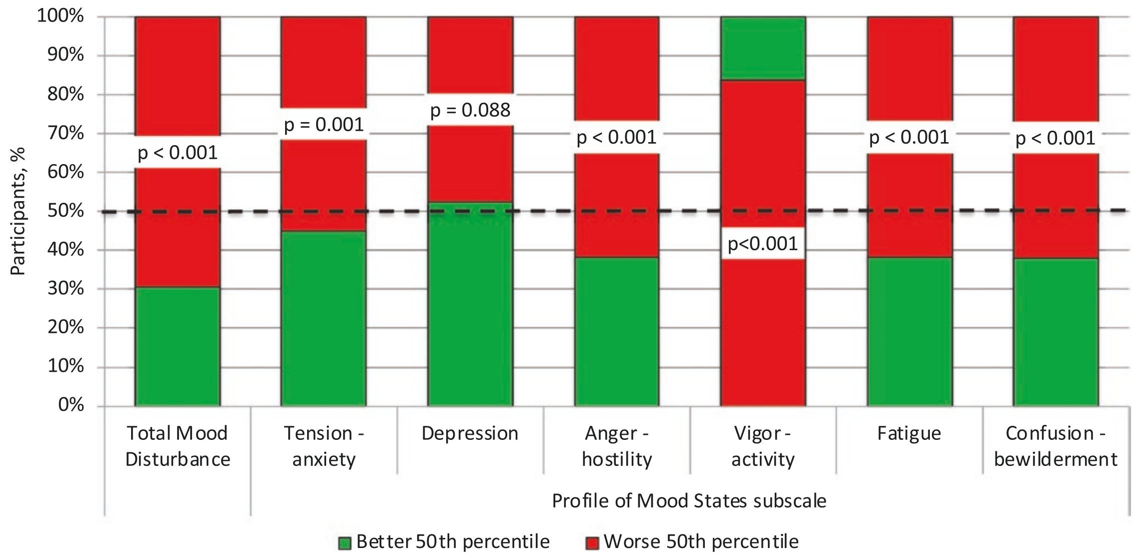

Figure 2. Percentage of sailors with POMS scores below or above the 50th percentile of adult norms.

Table 2. Explanatory Variables Associated With POMS Scores

POMS scale	Entire model		P-values of explanatory variables					
	R^2adj	P-value	Age	Sex	Occupational group	Watchstanding status	Watch schedule type (fixed, rotating)	Daily sleep duration
Total mood disturbance (TMD)[a]	0.096	<0.001	<0.001	0.936	0.247	0.030	<0.001	0.032
Tension-anxiety[a]	0.049	<0.001	0.003	0.952	0.256	0.108	0.001	0.213
Depression[a]	0.044	<0.001	0.003	0.748	0.308	0.182	0.022	0.328
Vigor-activity	0.091	<0.001	0.062	0.109	0.348	0.103	0.937	0.342
Anger-hostility[a]	0.101	<0.001	<0.001	0.101	0.184	0.136	<0.001	0.012
Fatigue[a]	0.101	<0.001	0.147	0.820	0.725	<0.001	<0.001	<0.001
Confusion-bewilderment[a]	0.048	<0.001	0.007	0.604	0.740	0.110	<0.001	0.079

Analysis conducted on data from 663 Sailors with questionnaire and actigraphy data after we excluded Sailors standing watch on atypical schedules or two-section fixed schedules (none of the Sailors was working two-section rotating schedules). Results adjusted for ship.
[a]Box-Cox transformation applied.

(denoted by the average number of sleep episodes per day), and (2) a larger number of sleep episodes per day for those participants who napped.

The two quartile groups also differed in terms of sleep quality as assessed by PSQI scores. Poor sleepers had a 52% higher risk of TMD scores in the fourth quartile. The same pattern was identified in ESS and ISI scores. Specifically, average daytime sleepiness was more severe (higher ESS scores) in the fourth quartile group. Sailors showing symptoms of EDS (ESS score > 10) had a 200% higher risk of having a TMD score in the fourth quartile group. Also, insomnia symptoms were more severe (higher ISI scores) in the fourth quartile group. Sailors with symptoms of clinically significant insomnia (ISI scores ≥ 15) had a 576% higher risk of scoring high on the POMS TMD scale. Of note, sailors with symptoms of clinically significant insomnia and symptoms of EDS were approximately 15 times more likely to have a POMS TMD score that would classify them in the fourth quartile group.

Lastly, we assessed differences between sailors in the study sample and the adult norms. As expected, sailors in the first and the fourth quartile groups tended to cluster in the better or worse 50th percentile groups of the adult norms, respectively. This pattern, however, was not seen in the vigor-activity scores. Specifically, 66.2% of sailors in the first quartile group had a vigor-activity score which was worse than the 50th percentile of adult norms (one-sided binomial test, $p < 0.001$). Detailed results are shown in Figure 3.

Discussion

The purpose of this study was to investigate the relationship between mood and sleep, sleep-related practices and behaviors of US Navy active-duty sailors. The results indicate that sailors slept less than what is recommended for adults of their age [15]. Sailors also reported negative appraisals of their own sleep health to include daytime sleepiness, insomnia, and poor sleep patterns, which may have led to a high prevalence of napping. We also found that sailors with poorer mood tended to use nicotine/tobacco products, did not exercise, and worked longer hours. Lastly, we found strong associations between poor sleep health and lower mood states.

Previous research identifies the effects that insufficient sleep can also have on numerous aspects of human performance to include lapses in attention and vigilance [34], decision-making

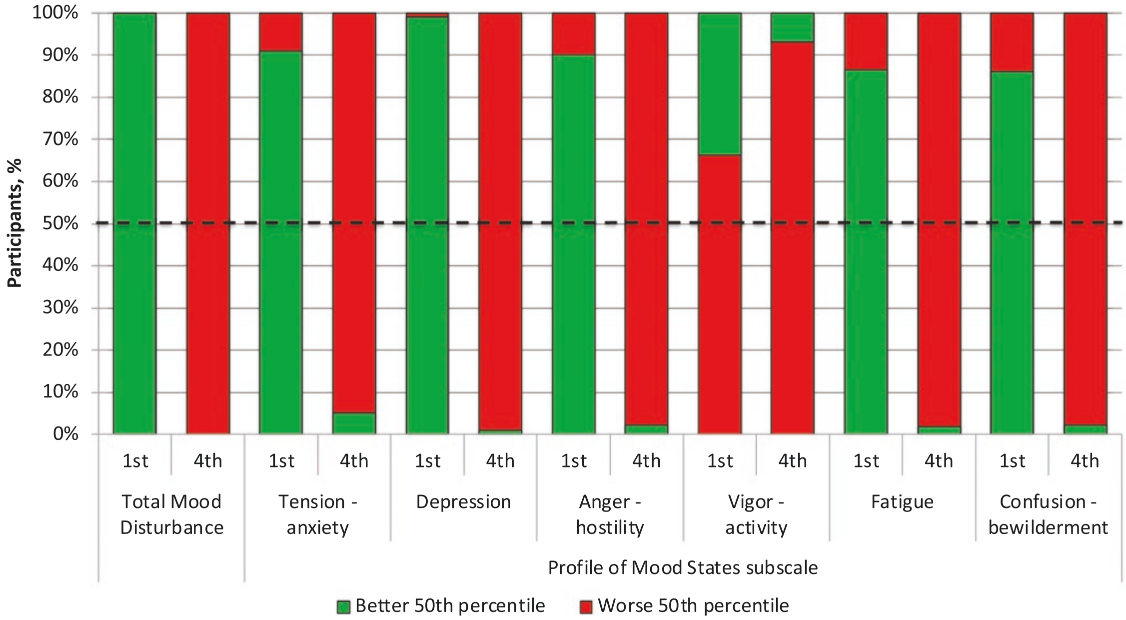

Figure 3. Percentage of sailors with POMS scores below or above the 50th percentile of adult norms. Contrast between the first and the fourth quartile groups.

[35], risk-taking [36], and athletic performance [37]. The results of this study indicate that sub-optimal sleep conditions exist on underway US Navy ships. Given that tangible consequences between inadequate crew sleep and military performance have been observed in numerous maritime mishaps [38], these findings may also have consequences for sailor and fleet safety and performance.

Sleep deprivation can also have detrimental effects on mood and affect [39]. While the emotional effects of sleep debt may be increased irritability or feeling "grumpy," these effects can have much more dire consequences in a military context. Considering that a quarter of the sailors in our study reported symptoms of clinically significant insomnia, and that sailors with these reported symptoms were 576% more likely to report low mood scores, the risk to Navy crews is apparent. Sleep debt can also impair the ability to integrate emotion and cognition to guide moral judgments [40], and sleep-deprived individuals react to situations more emotionally, especially with negative emotions [41]. In military operational settings—when decisions can mean life or death—moral judgment and emotional stability must be preserved to the greatest extent possible.

Poor sleep health may also undermine leadership effectiveness and the military chain of command—hallmarks of effective military operations. Multiple studies assessing the effects of sleep on leader-follower relationships have found that sleep debt negatively affects perceptions of relationship quality and increases workplace hostility [42]. Sleep-deprived leaders were more impatient, irritable, and antagonistic, and unaware of the negative dynamic [43]; and leaders who were sleep-deprived were perceived as significantly less inspirational or charismatic [44]. In the current study, we did not assess sailor opinions of other sailors' or leaders' moods. However, the consequences of poor sleep health aboard Navy vessels could have negative consequences for sailor relationships and the chain of command, and these effects could be unbeknownst to the crew. Further research investigating sleep and its effects on military chain of command is needed.

Inadequate sleep in a military context may also have long-term effects on military service members and veterans. In a remarkable study of medical students by Chang and colleagues, self-reported sleep health was provided by 1053 male medical students over a 16-year period (1948–1964), and their mental health was tracked for up to 45 years following graduation [45]. Of the original students studied, 101 men developed clinical depression and 13 died of suicide. Controlling for other risk factors (e.g. age, family history of depression, and measure of temperament), the relative risk of clinical depression was greater for those students who reported insomnia, difficulty sleeping, poor quality of sleep, and shorter sleep durations while attending medical school. These striking results indicate that sleep patterns in this population of young males placed them at greater risk for subsequent psychiatric distress and clinical depression, and this elevated risk persisted for 30+ years. Given the similarities between ADSM populations and medical students (age, high stress, long hours, etc.), the Chang et al. results may shed light on the long-term impacts of inadequate sleep in military populations.

Finally, while the mental health of participants in this study was not directly evaluated, their reported mood states may provide some indications of overall well-being. The mood scale used in this study (POMS) was originally developed to assess transient psychological mood [28] and is highly correlated with numerous other mental health assessment instruments [46]. Given the high prevalence of insufficient sleep in the military and the sobering statistics regarding active-duty military and veteran suicide rates, more research is needed to understand the relationship between sleep and mental health in military populations.

Limitations

The current study has several limitations which should be taken into consideration and may help inform future efforts. First, because they were cleared for underway deployment on US Navy ships, all the sailors studied were deemed to be fit for duty. However, we did not directly assess their health status. We did inquire about the medications they were taking, both prescription and over-the-counter. Adding questionnaires that more directly address the physical and mental health status of participants would be valuable additions to future studies.

In the current study, all responses were anonymous, and participants were reminded that their answers and their individual identities would not be disclosed. However, due to the nature of some of the questions, some participants may have been reluctant to answer honestly for fear of jeopardizing their careers.

Our overall study sample was large and, in general, representative of the demographic and occupational groups on the ships we studied. To increase the reliability and generalizability of our findings, future efforts should include larger samples of certain groups (e.g. senior enlisted and senior officers). By increasing the sample size, the effect of department, ship leadership, ship size, ship missions, and interactions of other potential predictive factors such as watch section or specific sailor duties could be explored more thoroughly. Furthermore, while we found strong relationships between sleep and mood, we cannot provide conclusive answers regarding the direction of these findings given the data presented here. Lastly, we used the widely accepted criteria to classify participants based on their ESS, ISI, and PSQI scores. Results from a number of studies, however, have emphasized the need for further validation of these tools in military populations [47, 48].

Conclusions

The results presented here highlight a widespread sleep deficit experienced by sailors on eight US Navy ships while underway. In addition to objective measures of sleep debt recorded by wearable technologies, sailors also reported negative appraisals of their own sleep patterns. Sailors who reported lower mood states were also found to have poor sleep hygiene. These findings have important implications for sleep hygiene aboard US Navy ships and in other military contexts. Future work will expand on these findings to explore the contributions both sleep and mood have on the mental health of military service members.

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Author Contributions

Christopher McClernon (Writing—original draft [Equal], Writing—review & editing [Equal]), Panagiotis Matsangas (Data curation [Equal], Formal analysis [Equal], Methodology [Equal], Visualization [Equal], Writing—original draft [Supporting], Writing—review & editing [Supporting]), and Nita Shattuck (Conceptualization [Equal], Funding acquisition [Equal], Methodology [Equal], Project administration [Equal], Writing—review & editing [Equal]).

Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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