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Discriminating Between Fatigue and Sleepiness in the Naval Operational Environment

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Objective: To assess the similarities and differences between reported levels of fatigue and sleepiness as a consequence of working at sea. *Participants*: 767 crewmembers of a U.S. Navy ship. *Methods*: Retrospective analysis of a survey to include questions about demographics, caffeine consumption, sleep adequacy, the Epworth Sleepiness Scale (ESS), and the Fatigue Severity Scale (FSS). *Results*: ESS scores (8.41 ± 4.66) indicated that 32% of the participants had excessive daytime sleepiness (ESS score > 10), while approximately 7% had an ESS score of 16 or more. FSS scores (average FSS = 3.01 ± 1.37) indicated that 28% of the participants had elevated fatigue (FSS score ≥ 4). Even though ESS and FSS scores were correlated ($r = 0.39$), their association explained only 15% of the variability observed. In terms of behavioral and lifestyle patterns, crewmembers with elevated fatigue (FSS ≥ 4) reported getting less exercise than those reporting less fatigue. Individuals with excessive sleepiness (ESS > 10) reported higher caffeine consumption. Crewmembers with elevated fatigue and comorbid sleepiness (FSS ≥ 4 and ESS > 10) reported receiving less sleep than other crew members. *Conclusions*: These results suggest that subjective fatigue and subjective sleepiness, as measured by the FSS and ESS scales, are distinct constructs and both are consequences of working at sea. The scores on the two scales correlate differentially with behavioral and lifestyle patterns of the crewmembers.

Fatigue and *sleepiness* refer to two distinct underlying phenomena (see for example, Lichstein, Means, Noe, & Aguillard, 1997; Neu et al., 2010). *Sleepiness* results from the neurobiological processes regulating circadian rhythms and the drive to sleep (Dinges, 1995; Mullins, Cortina, Drake, & Dalal, 2014). Hence, sleepiness or actual somnolence occurs when individuals receive sleep of reduced length or quality, or following long hours of sustained wakefulness, which leads to an intense need for sleep. Given these causal factors, sleepiness is considered pathological when it occurs at an inappropriate time or in an atypical situation (Shahid, Shen, & Shapiro, 2010). For example, individuals with severe sleep debt have an increased risk of motor vehicle crashes because drowsiness compromises driving ability (Ohayon, Caulet, Philip, Guilleminault, & Priest, 1997; Pizza et al., 2015).

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On the other hand, *fatigue*, often defined as weariness after exertion (Colwell, 1989), refers to a feeling of strain and exhaustion (Phillips, 2015; Shahid et al., 2010; Shen, Barbera, & Shapiro, 2006); depends on the level of exertion (Lichstein et al., 1997); and is indicative of working long hours, having little rest, or being unable to sustain a certain level of performance on a task (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002; Dinges, 1995). Although there are a number of subjective and objective methods to measure sleepiness, fatigue is still assessed only through subjective means (Shahid et al., 2010; Shen, Barbera, et al., 2006).

Fatigue and sleepiness are terms that are frequently used interchangeably (Dinges, 1989), probably because the symptoms of both conditions are nonspecific and may coexist. For example, Merkelbach and Schulz (2006) investigated fatigue and sleepiness by using the Fatigue Severity Scale (FSS; Krupp, LaRocca, Muir-Nash, & Steinberg, 1989) and the Epworth Sleepiness Scale (ESS; Johns, 1991) respectively. Their results showed that a subset of items on the ESS was significantly correlated with fatigue as measured by the FSS and as such, were confounded. Bailes et al. (2006) came to the same conclusion about the constructs of fatigue and sleepiness.

Fatigue and sleepiness are evident in a number of psychiatric, medical, and primary sleep disorders (Shen, Barbera, et al., 2006). Fatigue is associated with depression (Karlsen, Larsen, Tandberg, & Jørgensen, 1999), and it is common in patients diagnosed with cancer (Smets, Garssen, Schuster-Uitterhoeve, & de Haes, 1993). Studies with patients with sleep disturbances or disorders and multiple sclerosis have shown that fatigue without sleepiness was prevalent while sleepiness without fatigue was rare (Hossain et al., 2005; Merkelbach & Schulz 2006). Sleepiness is also associated with both sleep disorders and mental illness (Ohayon et al., 1997). The correct identification of these two symptoms may drive clinical diagnosis and treatment (Shahid et al., 2010) and as such, it is important to differentiate between the two conditions (Shen, Barbera, et al., 2006).

Fatigue and sleepiness, even at nonpathological levels, are a major concern in the military operational environment because they negatively affect human performance. Sleepiness is associated with performance lapsing, cognitive slowing, memory problems, and time-on-task decrements (Dinges & Kribbs, 1991). Physiological fatigue is associated with a decline in the ability to exert and maintain force (Bigland-Ritchie, Rice, Garland, & Walsh, 1995; Latash, Danion, & Bonnard, 2003), and in postural control (Corbeil, Blouin, Bégin, Nougier, & Teasdale, 2003). Furthermore, many factors known to be associated with sleepiness and fatigue such as long working hours, high physical demands, stress and time pressure, are pervasive in the military environment. Compared to the general population, members of the military service report shorter sleep durations (Troxel et al., 2015).

Crew members on U.S. Navy ships live and work in conditions characterized by extreme sleep deprivation (Miller, Matsangas, & Kenney, 2012; Miller, Matsangas, & Shattuck, 2008) and fatigue due to working extended periods of 12 or more hours (Shattuck & Matsangas, 2014; Shattuck, Matsangas, & Powley, 2015). Furthermore, crew members perform their duties in a moving environment, which is known to lead to the development of motion-induced fatigue (Colwell, 1989; Haward, Lewis, & Griffin, 2009; Holmes, Robertson, & Crossland, 2002; Wertheim, 1998). Consequently, military personnel are expected to be at higher risk of elevated sleepiness and fatigue compared to the general population. Even though it is well documented that sleepiness affects performance (Miller et al., 2012), fatigue at sea is a not well-investigated phenomenon (Wertheim, 1998). Therefore, it was not a surprise that our review failed to identify any research focusing on the relationship between these two phenomena in active-duty crew members in their work environment.

As a step toward better assessment of fatigue at sea, the goals of this study were (a) to assess the similarities and differences between subjective reports of fatigue and sleepiness as a consequence of working in the naval operational environment, (b) to evaluate predictors of sleepiness and fatigue, and (c) to measure sleepiness and fatigue in the naval operational environment using validated scales. Our specific concern was whether fatigue and sleepiness, as measured by two widely used psychometrics scales, the FSS and ESS, have differential associations within a sample of Unites States Navy crewmembers.

METHODS

Participants

The study sample included 767 active duty U.S. Navy crewmembers serving aboard the USS NIMITZ (CNV-68), a U.S. Navy aircraft carrier. Crew members were deemed fit for duty (i.e., they passed the annual medical and physical examination test to be allowed to deploy), and were predominantly watchstanders. To enable continuous operations, crew members worked in shifts, that is, different groups of crew members rotate among themselves to perform the same jobs. During each shift, qualified personnel were required to work at specific stations on a recurring basis. In nautical terms, this practice is called watchstanding and the crew members working in shifts are, hence, called watchstanders.

Measures

The survey used included questions about demographics (e.g., age, gender, height, weight), whether the participant was required to stand watch, reported average sleep duration, frequency of exercise per week when deployed, and the use of sleep-promoting medication (either prescribed or over-the-counter). Used for body mass index (BMI) calculation, height and weight were measured during the body composition assessment (BCA) portion of the semiannual physical fitness assessment (PFA) check-in process and were reported by the participants. Previous research has shown that BMI is positively correlated with FSS scores (Impellizzeri, Agisti, De Col, & Sartorio, 2013).

Given the widespread use of caffeine to maintain wakefulness (Miller et al., 2012), participants were asked to report consumption of caffeinated beverages. Specifically, participants reported the number of 8-oz. cups of coffee they drank, the number of 12-oz. cans of caffeinated soft drinks, the number of 8-oz. cups or glasses of hot or iced tea, and the number of energy drinks. Participants also reported the adequacy of their sleep time while at sea ("much less then needed," "less than needed," "about right," "more than needed," and "much more than needed").

Lastly, the survey included two standardized questionnaires. The self-administered Epworth Sleepiness Scale (ESS) was used to assess daytime sleepiness (Johns, 1991). The ESS includes eight statements, each one representing a situation commonly encountered in daily life. Using a 4-point Likert scale, participants indicate their chance of dozing off or falling asleep in these eight situations. Responses are scored from 0 to 3, with 0 being "would never doze," 1 is "slight chance of dozing," 2 is "moderate chance of dozing," whereas 3 denotes a "high chance of dozing." The participants were instructed to rate themselves according to "your usual way of life in recent times." The total ESS score ranged from 0 to 24. A score greater than 10 reflects above normal daytime sleepiness (Johns, 1991, 1992). The questionnaire has a high level of internal consistency as measured by Cronbach's alpha, which ranges from 0.73 to 0.88 (Johns, 1992). Clinicians commonly use the ESS in office settings as a screening tool to identify individuals with excessive daytime sleepiness and potential sleep disorders. Some studies have questioned the reliability of the ESS for assessing sleep propensity as compared to the Mean Sleep Latency Test (MSLT; see for example, Chervin & Aldrich, 1999). The operational utility of the ESS, however, lies in its ability to assess average sleepiness in daily life (Johns, 1994) and to identify individuals who are at higher risk of psychomotor performance impairment (Shattuck & Matsangas, 2015d).

The 9-item, self-reported Fatigue Severity Scale (FSS) was used to assess fatigue (Krupp et al., 1989). Based on 7-point Likert scales for each question, the FSS score is the average of the item scores; lower scores indicate less fatigue while higher scores indicate more fatigue. By design, the FSS is predominantly focused on the assessment of the impact of fatigue on daily functioning (Krupp et al., 1989). The tool has high internal consistency with Cronbach's alpha ranging between 0.81 and 0.89 (Krupp et al., 1989). To identify elevated fatigue levels, we used a cutoff score of FSS ≥ 4 (Krupp et al., 1989).

Procedures

This work was part of a broader, cross-sectional study designed to assess the prevalence of musculoskeletal symptoms in active duty personnel (Shattuck, Matsangas, Moore, & Wegemann, 2015). All surveys were administered on the USS Nimitz in the spring of 2014 during the BCA portion of the semiannual PFA. Prior to completing the study questionnaire, participants were not given any information or explanation regarding fatigue or sleepiness. The Naval Postgraduate School Institutional Review Board approved the study protocol and the requirement for a documented consent was waived. During the PFA process, crew members were administered a printed page with information about the study. Interested crew members then completed the survey.

Analytical Approach

In the first stages of the analysis, we addressed issues with missing data. ESS and FSS scores were not calculated when more than two responses were missing. Up to two missing responses were interpolated by the most frequent response of each participant. Overall, 28 ESS item responses (0.37%) were interpolated for 22 participants, whereas 34 FSS item responses (0.49%) were interpolated for 31 participants. Forty-one crewmembers did not respond to either the ESS or FSS or to both questionnaires.

Based on the reported consumption of caffeinated beverages (i.e., coffee, caffeinated soft drinks, tea, and energy drinks) and caffeine content of each bottle, can, or cup (Clauson, Shields, McQueen, & Persad, 2003; Reissig, Strain, & Griffiths, 2009), the approximate weekly caffeine intake was calculated. The BMI for each subject was calculated using the reported height and weight data and the formula: BMI = weight in pounds X 703 /(height in inches)^2. Classification was performed using the World Health Organization's BMI cutoffs: underweight for BMI less than 18.50 kg/m^2, normal range for BMI 18.50 to 24.99 kg/m^2, overweight range for BMI 25 to 29.99 kg/m^2, and obese for BMI more than 30 kg/m^2.

All variables initially underwent descriptive analysis to identify anomalous entries and to determine demographic characteristics. To assess differences in behavioral and lifestyle patterns, participants were classified into four groups based on their ESS and FSS scores. Those with ESS score > 10 and FSS score ≥ 4 were included in the “Fatigued and Sleepy” group, whereas participants with ESS score ≤ 10 and FSS score < 4 were included in the “Neither Fatigued Nor Sleepy” group. The rest of the participants were included in the “Fatigued but not Sleepy” (FSS score ≥ 4 and ESS ≤ 10), or the “Sleepy but not Fatigued” group (FSS score < 4 and ESS > 10).

Statistical analysis was conducted with JMP statistical software (JMP Pro 12; SAS Institute; Cary, North Carolina). Results are presented as mean (*M*) ± standard deviation (*SD*). Significance level was set at $p < 0.05$. The Wilcoxon Rank Sum test and the Fisher’s exact test were used for pairwise comparisons, whereas Dunn’s Method for Joint Ranking was used for multiple comparisons. Associations between continuous variables were assessed by Pearson’s *r* correlation coefficient.

RESULTS

We had 767 respondents out of a total sample of 2,500 with a response rate of approximately 30%. Demographic characteristics are shown in Table 1. The reported average daily sleep duration was 6.12 ± 1.10 hr, with approximately 70% of our participants sleeping less than 7 hr per day. Over half of the respondents (53.7%) rated the amount of sleep they received at sea as less than needed, compared to just 2.14% who reported sleeping more than needed.

Correlation analysis over the entire data set showed that ESS and FSS scores were associated (Pearson’s $r = 0.390$, $p < 0.001$) even after adjusting for age, gender, BMI, and

TABLE 1
Demographic Characteristics

	M ± *SD*	*Range*
Age	25.4 ± 5.94	18–49
Gender, no. (% male)	507 (66.6%)	
Watchstanders, no. (%)	444 (62.6%)	
BMI	25.1 ± 3.34	15.5–38.6
Underweight, no. (%)	12 (1.87%)	
Normal weight, no. (%)	311 (48.4%)	
Overweight, no. (%)	274 (42.7%)	
Obese, no. (%)	45 (7.03%)	
Exercise frequency, times per week	3.98 ± 1.76	0.5–12
Daily sleep duration, hours	6.12 ± 1.10	2.5–10
Sleep promoting medication, no. (%)	81 (11.1%)	
ESS score	8.41 ± 4.66	0–24
Excessive daytime sleepiness		
ESS score > 10), no. (%)	237 (31.8%)	
ESS score ≥ 16), no. (%)	53 (7.11%)	
FSS score	3.01 ± 1.37	1–7
Elevated fatigue (FSS score ≥ 4), no. (%)	204 (28.1%)	

Note. Sample size $N = 767$.

sleep medications. The association between ESS and FSS, however, explained only 15% of the observed variability. The lack of a stronger association between the ESS and FSS scores was also supported by the fact that 51% of the participants with elevated fatigue (FSS ≥ 4) did not report excessive daytime sleepiness (ESS ≤ 10), whereas 57% of the participants with excessive daytime sleepiness (ESS > 10) did not have elevated fatigue. ESS and FSS data are depicted in the scatterplot in Figure 1. A regression line is also provided.

Next, we assessed differences between group characteristics in terms of age, gender, watchstanding, BMI, exercise frequency, reported daily sleep duration. Multiple comparisons using Dunn's method for joint ranking showed that age, frequency of exercise, sleep duration, and the consumption of caffeine differed between groups (Table 2). ESS and FSS scores by group are also shown in Table 2. Gender and BMI did not differ between groups ($p > 0.80$).

Table 2 shows three interesting patterns of results. The two nonfatigued groups (NFNS, SNF) tended to exercise more frequently than the fatigued groups (FS, FNS; comparison between NFNS+SNF and FS+FNS, Wilcoxon Rank Sum test, Z = 4.41, $p < 0.001$, effect size $r = 0.177$). The Fatigued and Sleepy (FS) group consumed significantly more caffeine than the NFNS and the FNS groups. The FS group also reported receiving significantly less sleep than the three other groups. It is interesting that the ESS and FSS scores were not associated with watchstanding within any of the groups, or in the entire sample (Fisher's Exact test, $p > 0.60$). Furthermore, the two sleepy groups (FS, SNF) reported sleeping less than the nonsleepy groups (NFNS, FNS; comparison between FS+SNF and NFNS+FNS, Wilcoxon Rank Sum test, $Z = 4.49$, $p < 0.001$, effect size $r = 0.197$).

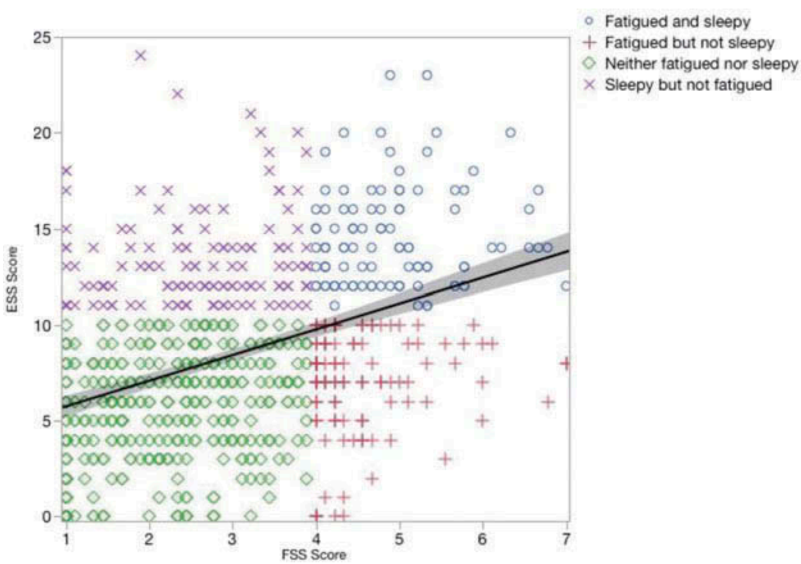

FIGURE 1 ESS versus FSS scores.

TABLE 2
Characteristics by Group

	Fatigued and sleepy (FS)	*Fatigued but not sleepy (FNS)*	*Neither fatigued nor sleepy (NFNS)*	*Sleepy but not fatigued (SNF)*	*Differences*
Age, $M \pm SD$	26.5 ± 6.27	25.9 ± 5.82	25.2 ± 5.86	24.7 ± 6.12	SNF ≠ FNS, $p = 0.049$; SNF ≠ FS, $p = 0.01$
Daily sleep, $M \pm SD$ hr	5.58 ± 1.10	6.26 ± 1.09	6.21 ± 1.08	6.07 ± 1.03	FNS ≠ FS, $p < 0.001$; NFNS ≠ FS, $p < 0.001$; SNF ≠ FS, $p = 0.002$
Exercise, $M \pm SD$ times/week	2.83 ± 2.05	3.11 ± 1.96	3.85 ± 2.06	3.73 ± 1.92	NFNS ≠ FS, $p = 0.001$; SNF ≠ FS, $p = 0.007$; NFNS ≠ FNS, $p = 0.034$
Caffeine intake, $M \pm SD$ mg	990 ± 1072	532 ± 493	656 ± 740	847 ± 1301	FS ≠ NFNS, $p = 0.044$; FS ≠ FNS, $p = 0.042$
ESS score, $M \pm SD$	14.5 ± 2.62	7.02 ± 2.62	5.57 ± 2.89	13.5 ± 2.54	NA
FSS score, $M \pm SD$	4.91 ± 0.737	4.56 ± 0.684	2.25 ± 0.862	2.57 ± 0.897	NA

Note. [A]Statistical differences between groups based on Dunn's method for joint ranking.

DISCUSSION

As measured by FSS and ESS scores respectively, the results of this study support the distinction between fatigue and sleepiness in active-duty navy personnel working at sea. Approximately 51% of the participants with elevated fatigue (i.e., FSS ≥ 4) did not report excessive daytime sleepiness (ESS ≤ 10), whereas 57% of the participants with excessive daytime sleepiness (ESS > 10) did not have elevated fatigue.

Even though distinct, the modest correlation ($r = 0.39$) between fatigue and sleepiness scores also shows the partial overlap between the two constructs, which is aligned with neural research (Mehta & Parasuraman, 2014). Our results, however, agree with earlier findings showing that the association between ESS and FSS may be statistically significant in some cases but it is not strong (Hossain et al., 2005; Shen, Botly, et al., 2006). In contrast, the study by Merkelbach and Schulz (2006) found a significant correlation between ESS and FSS scores ($r = 0.52$, $p < 0.01$).

We also identified differences in some behaviors between participants who were predominantly fatigued and those who were predominantly sleepy. Specifically, our results showed that the frequency of exercise was associated with the reported level of fatigue but not with level of sleepiness. Regardless of their level of sleepiness, crew members with elevated fatigue exercised less frequently than their counterparts who did not report elevated fatigue. Furthermore, crew members with excessive daytime sleepiness and comorbid elevated fatigue consumed caffeine at levels comparable to their sleepy peers who did not demonstrate elevated fatigue, and significantly more caffeine than crew members without excessive daytime sleepiness.

These results emphasize the association between sleep deprivation, sleepiness, and caffeine consumption (Shattuck & Matsangas, 2015a). Our participants slept on average 6.12 ± 1.10 hr, with approximately 70% of the participants being sleep deprived, that is, sleeping less than 7 hr per day (Watson et al., 2015). This finding is aligned with more than 15 years of sleep research conducted at the Naval Postgraduate School showing that the majority of crew members are chronically sleep-deprived, receiving 5 to 6 hr of sleep per day (Miller et al., 2012; Shattuck & Matsangas, 2015b). The effect of restricted sleep at sea is further magnified by the poor quality of sleep that most crew members get, primarily for two reasons. First, they are working in shifts; therefore, they sleep at irregular times (Shattuck & Matsangas, 2015c). Second, crew members sleep in berthing compartments in which environmental noise (other crew members in the same compartment, external noises, etc.) disrupts their sleep (Shattuck, Matsangas, & Brown, 2015). Hence, crew members are sleep-deprived due to both quantity and quality of sleep. This chronic situation may lead to elevated daytime sleepiness which, in turn, can lead to greater caffeine consumption. Even though studies in controlled conditions have showed that caffeine consumption may lead to sleep disruption (Karacan et al., 1976), we believe that the major explanation for sleep deprivation in the naval environment is the restricted opportunities to sleep at circadian-appropriate times (Shattuck & Matsangas, 2015c). Previous research has demonstrated that crew members working on circadian-based watch schedules receive better sleep, feel more alert, and their caffeine consumption is reduced (Shattuck, Matsangas, & Brown, 2015).

We should also note that the extent of sleep deprivation in our sample is further shown by the finding that approximately 7% of the crew members had an ESS score of 16 or more, indicating a high level of daytime sleepiness. In his study introducing ESS, Johns (1991) identified such high ESS scores in patients with narcolepsy, idiopathic hypersomnia, or obstructive sleep apnea.

Notably, crew members reporting elevated fatigue and comorbid sleepiness reported receiving significantly less sleep than the three other groups. Those participants who were classified as sleepy but not fatigued reported receiving less sleep than the nonsleepy crew members, but this difference was not statistically significant. The interaction between sleep and fatigue has been identified in a longitudinal study using actigraphy to assess sleep (Åkerstedt, Axelsson, Lekander, Orsini, & Kecklund, 2014). The Åkerstedt and colleagues study showed that the quality and the duration of prior sleep are factors associated with how fatigue is experienced. Specifically, elevated fatigue was associated with reduced sleep duration and poor sleep quality.

Interestingly, in our sample, neither ESS nor FSS scores were associated with standing watch. These results do not support findings by Shen et al. (2006) who found that the frequency of shift work has a significant effect on subjective fatigue, but not on subjective sleepiness. A possible explanation may be that Shen et al. used a civilian sample, whereas our sample included active duty crew members working on a U.S. Navy ship. Even though a typical workday at sea is between 11 and 15 hr in length, watchstanding may comprise only 6 to 12 hr of the workday (Shattuck & Matsangas, 2014; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015). Since watchstanding represents only 50% to 60% of the workday of many of our crew members, it is reasonable to expect that the fatigue and sleepiness levels of the crew may not be associated with watchstanding per se, but with the weariness imposed by such excessively long workdays.

Overall, our results suggest that sleepiness and fatigue, as measured by the ESS and FSS scales, are two distinct constructs, which correlate differentially with behavioral and lifestyle patterns of crew members in the naval operational environment. Future efforts should assess how ESS and FSS scores differ between different watch schedules and in various sea states under conditions in which crew members may also suffer from symptoms of motion sickness and sopite syndrome (Matsangas & McCauley, 2014). A better understanding of sleepiness and fatigue severity may lead to more effective macroergonomic interventions and better designed work schedules while at sea.

Study Limitations

This study has a number of limitations. Daily sleep duration is self-reported. The prevalence of excessive daytime sleepiness was based on the widely accepted cutoff criterion of ESS score > 10. To identify elevated fatigue levels, we used the cutoff point suggested by Krupp et al. in their 1989 paper, that is, FSS score ≥ 4. However, this cutoff point has not received wide acceptance. Whereas some researchers use an FSS score ≥ 4 to identify elevated fatigue levels (Armutlu et al., 2007; Krupp et al., 1989; Valko, Bassetti, Bloch, Held, & Baumann, 2008), others have used an FSS score ≥ 5.4 to indicate clinically significant fatigue in patients with major depression (Ferentinos, Kontaxakis, Havaki-Kontaxaki, Dikeos, & Lykouras, 2011). Still others have used an FSS score of > 3 to indicate fatigue (Hossain et al., 2005; Merkelbach & Schulz, 2006). When we applied two different criterion (an FSS cutoff score ≥ 3 or an FSS cutoff score of ≥ 5), we arrived at the same pattern of results.

Participants were asked whether they were watchstanders without assessing more detailed information about the characteristics of their watch schedule. Given that crew members on ship are chronic shift workers, future efforts should assess how characteristics of the watch schedule may affect FSS scores. Lastly, since this study was epidemiological in nature, causal associations cannot be established.

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