NPS-OR-15-005

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

PREVALENCE OF MUSCULOSKELETAL SYMPTOMS, EXCESSIVE DAYTIME SLEEPINESS, AND FATIGUE IN THE CREWMEMBERS OF A U.S. NAVY SHIP

by

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April 2015

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Prepared for: Advanced Medical Development Program, Naval Medical Research Center, Silver Spring, MD 20910

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REPORT DOCUMENTATION PAGE	*Form Approved* OMB No. 0704-0188

1. REPORT DATE*(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From-To)*
30-04-2015	Technical Report	May 2014 – December 2014

4. TITLE AND SUBTITLE
Prevalence of Musculoskeletal Symptoms, Excessive Daytime Sleepiness, and Fatigue in the crewmembers of a U.S. Navy Ship

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
Operations Research Department
Naval Postgraduate School
Monterey, CA 93943

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-OR-15-005

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
CDR Sheri Parker
Advanced Medical Development Program
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Silver Spring, MD 20910

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The views expressed in this report are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

14. ABSTRACT
This epidemiological, cross-sectional, questionnaire-based study has two goals. The first goal is to assess the prevalence of musculoskeletal (MSK) symptoms, fatigue levels, and use of caffeinated beverages in a sample of active duty personnel in the U.S. Navy. Second, the study seeks to explore the associations among musculoskeletal symptoms, reported sleep, daytime alertness, and fatigue levels. During the weigh-in portion of their semiannual Physical Readiness Test in Spring 2014, crewmembers of a U.S. Navy aircraft carrier were invited to complete an anonymous survey. The survey contained questions pertaining to demographics, exercise frequency, average sleep duration, caffeine consumption, the Epworth Sleepiness Scale (ESS), the Nordic Musculoskeletal Symptoms Survey, and the Fatigue Severity Scale (FSS). We had 767 respondents; approximately, a 30% response rate. Two-thirds of the sample was male. The average age was 25.4 ± 5.94 years; ranging from 18 to 49. Approximately 43% of the sample was overweight and 7% obese. At least one type of caffeinated beverage was used by 88.3% of the participants. Participants reported receiving approximately six hours of sleep per day while at sea; more than 50% of them rated their sleep as less than needed and 31.8% reported increased daytime sleepiness (ESS scores > 10). Approximately 9% of the participants reported an FSS score greater than or equal to 5, suggesting elevated fatigue levels. Approximately 58% of the respondents reported at least one MSK symptom in the last 12 months, 44% reported at least one symptom in the last seven days, and 20.4% reported that MSK symptoms prevented them from carrying out their normal activities. Regarding the 12-month prevalence, the lower back (39.5%) and knees (33.6%) were the two body parts most frequently reported for MSK symptoms. Symptoms in these two body parts were also the most frequently reported as preventing participants from normal activities. Older crewmembers were more likely to report MSK symptoms, and females reported more MSK symptoms than males. The occurrence of MSK symptoms was associated with elevated fatigue levels and excessive daytime sleepiness. Compared to crewmembers without MSK symptoms, crewmembers with MSK symptoms are more likely to report elevated daytime sleepiness (g=0.26 – 0.39), increased levels of fatigue (g=0.54 – 0.59) and are more likely to use sleep-promoting medications. Crewmembers reporting MSK symptoms were more likely to consume caffeinated beverages.

15. SUBJECT TERMS
Musculoskeletal symptoms, fatigue, sleepiness

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
Unclassified	Unclassified	Unclassified	UU	49	Nita Lewis Shattuck
					19b. TELEPHONE NUMBER*(include area code)* (831) 656-2281

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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The report entitled "Prevalence of Excessive Daytime Sleepiness, Fatigue and Musculoskeletal Symptoms in the Crew of a U.S. Navy Ship" was prepared for U.S. Navy Advanced Medical Development Program, Silver Spring, MD 20910.

Further distribution of all or part of this report is authorized.

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ABSTRACT

This epidemiological, cross-sectional, questionnaire-based study has two goals. The first goal is to assess the prevalence of musculoskeletal (MSK) symptoms, fatigue levels, and use of caffeinated beverages in a sample of active duty personnel in the U.S. Navy. Second, the study seeks to explore the associations among musculoskeletal symptoms, reported sleep, daytime alertness, and fatigue levels.

During the weigh-in portion of their semiannual Physical Readiness Test in Spring 2014, crewmembers of a U.S. Navy aircraft carrier were invited to complete an anonymous survey. The survey contained questions pertaining to demographics, exercise frequency, average sleep duration, caffeine consumption, the Epworth Sleepiness Scale (ESS), the Nordic Musculoskeletal Symptoms Survey, and the Fatigue Severity Scale (FSS).

We had 767 respondents; approximately, a 30% response rate. Two-thirds of the sample was male. The average age was 25.4 ± 5.94 years; ranging from 18 to 49. Approximately 43% of the sample was overweight and 7% obese. At least one type of caffeinated beverage was used by 88.3% of the participants. Participants reported receiving approximately six hours of sleep per day while at sea; more than 50% of them rated their sleep as less than needed and 31.8% reported increased daytime sleepiness (ESS scores > 10). Approximately 9% of the participants reported an FSS score greater than or equal to 5, suggesting elevated fatigue levels. Approximately 58% of the respondents reported at least one MSK symptom in the last 12 months, 44% reported at least one symptom in the last seven days, and 20.4% reported that MSK symptoms prevented them from carrying out their normal activities. Regarding the 12-month prevalence, the lower back (39.5%) and knees (33.6%) were the two body parts most frequently reported for MSK symptoms. Symptoms in these two body parts were also the most frequently reported as preventing participants from normal activities. Older crewmembers were more likely to report MSK symptoms, and females reported more MSK symptoms than males. The occurrence of MSK symptoms was associated with elevated fatigue levels and excessive daytime sleepiness. Compared to crewmembers without MSK symptoms, crewmembers with MSK symptoms are more likely to report elevated daytime sleepiness (g=0.26 – 0.39), increased levels of fatigue (g=0.54 – 0.59) and are more likely to use sleep-promoting medications. Crewmembers reporting MSK symptoms were more likely to consume caffeinated beverages.

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I. INTRODUCTION

Musculoskeletal (MSK) disorders include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels (Punnett & Wegman, 2004). In addition to recognized clinical syndromes, such as tendon inflammation and muscle strain, MSK disorders may also include less well-defined conditions such as myalgia, low back pain, and other regional pain syndromes (Punnett & Wegman, 2004). Work-related MSK symptoms and disorders are associated with two groups of factors: biomechanical or physical aspects of the work involved and psychosocial factors (Devereux, Vlachonikolis, & Buckle, 2002; Faucett, 2005; Golubovich, Chang, & Eatough, 2014; Parks, Carnell, & Farmer, 2005; Punnett & Wegman, 2004; Steering Committee for the Workshop on Work-Related Musculoskeletal Injuries: The Research Base, 1998; Widanarko, Legg, Devereux, & Stevenson, 2014). Physical work factors include physical workload, rapid work pace, repetitive movements, nonneutral body postures, manual material handling, and whole-body vibration (Bernard, 1997; Devereux et al., 2002; Holmström & Engholm, 2003; Punnett & Wegman, 2004; Steering Committee for the Workshop on Work-Related Musculoskeletal Injuries: The Research Base, 1998).

Research has also shown that psychosocial factors affect the development of MSK disorders and symptoms (Carayon, Smith, & Haims, 1999; Chen, Yu, & Wong, 2005; Faucett, 2005; Punnett & Wegman, 2004; Steering Committee for the Workshop on Work-Related Musculoskeletal Injuries: The Research Base, 1998). The term “psychosocial” includes both behavioral and psychological components of the job (Carayon, Haims, & Yang, 2006), such as social support and work organization (i.e., the way in which work is organized, processed, and supervised [Hagberg et al., 1995]). Psychosocial factors include work stress, psychological job demands, low social support, and job dissatisfaction (Bernard, 1997; Devereux et al., 2002; Golubovich et al., 2014; Punnett & Wegman, 2004; Widanarko et al., 2014).

The link between the characteristics of the work conditions and the effects on the workers is job stress (i.e., the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources, or needs of the worker (Sauter et al., 1999). According to the National Institute for Occupational Safety and Health (NIOSH) view, exposure to stressful working conditions can have a direct influence on worker safety and health, whereas individual and other situational factors can intervene to strengthen or weaken this influence (Sauter et al., 1999).

Epidemiological investigations have assessed MSK injuries at sea. MSK injuries may increase lost duty days by preventing personnel from carrying out normal job activities, or interfering with sailors' ability to complete their tasks and duties in a timely manner. A 1997 study aboard a deployed U.S. Navy aircraft carrier found that MSK injuries more often resulted in lost duty days, compared to other types of injuries (Krentz & Baker, 1997). A 2004 study onboard a U.S. Navy aircraft carrier during two consecutive 6-month deployments found that MSK visits accounted for 55% of the total medical visits (Hebert & Pasque, 2004). This retrospective study also found that hand/wrist, back/neck, and knee injuries had the highest incidence aboard both ships. In 2000, a 90-day study was conducted to assess MSK injuries during a predeployment phase on a U.S. Navy ship (Balcom & Moore, 2000). Three anatomical sites had the highest incidence of injury: knee and leg, back and chest, and hand/wrist. Calendar year 2013 MSK injury data, extracted from inpatient and outpatient medical encounter records from four U.S. Navy aircraft carriers, showed that shoulder, hand/wrist, and ankle/foot injuries had the highest incidence rates *(Musculoskeletal injuries among sailors aboard aircraft carriers*, *2013*, 2014).

Another issue of concern is the association between MSK symptoms and extended work hours, a common problem of life at sea (Green, 2009; Haynes, 2007; Mason, 2009). Research has shown that frequent overtime work and extended work hours using video monitors are associated with increased occurrence of MSK symptoms of the neck and the upper limbs (Bergqvist, Wolgast, Nilsson, & Voss, 1995; Fredriksson et al., 1999; Veiersted & Waersted, 1999). Another study investigated the relationship between the combination of work-schedule characteristics and reported MSK disorders among nurses working extended hours (Lipscomb, Trinkoff, Geiger-Brown, & Brady, 2002). Results showed that the combination of working shifts longer than 12 hours per day, with 40 or more hours of work per week, was associated with increased risk for neck, shoulder, and back disorders, compared to other work schedules.

Ship crews live and work in an environment characterized by extreme sleep deprivation (Miller, Matsangas, & Kenney, 2012; Miller, Matsangas, & Shattuck, 2008). In an attempt to maintain alertness, crewmembers commonly consume caffeinated beverages and energy drinks. Caffeine is a widely used central nervous system stimulant (Greenwood & Oria, 2008). In working conditions where chronic sleep restriction is common, caffeine may be an effective fatigue countermeasure (Miller et al., 2012); however, use of caffeine, especially timed close to a major sleep period, may also interfere with sleep.

Marketed to improve energy, stamina, athletic performance, and concentration, energy drinks are beverages containing caffeine, taurine, sugar or sweeteners, and vitamins (Seifert, Schaechter, Hershorin, & Lipshultz, 2011). The caffeine content in caffeinated beverages varies with can size and concentration of caffeine (milligrams per ounce). Depending on the serving size, an energy drink may contain from 50 milligrams (mg) to 505 mg of caffeine, corresponding to 5.9-171 mg/oz (Reissig, Strain, & Griffiths, 2009). Energy drink consumption reportedly leads to increased alertness and a better mood (Smit & Rogers, 2002). The major demographic target groups for the marketing of energy drinks are teenagers and young adults, 18 to 34 years old (Heckman, Sherry, & Gonzalez de Mejia, 2010). These age groups encompass approximately 56% of officers and 85% of all enlisted active duty personnel in the U.S. armed forces *(2012 Demographics: Profile of the Military Community*, 2014).

Recent research shows a significant increase in the consumption of energy drinks in combat environments. Forty-five percent of U.S. service members surveyed in Afghanistan in 2010 reported consuming energy drinks daily (Toblin, Clarke-Walper, Kok, Sipos, & Thomas, 2012). Service members who report using three or more energy drinks a day (14%) also report sleeping less, having more sleep disruptions from stress and illness, and falling asleep on guard duty and in briefings more frequently than those individuals drinking two or fewer energy drinks a day. The consumption of energy drinks continues to garner attention as an emerging public health risk primarily due to their high content of caffeine and sugar (Arria & O'Brien, 2001; Pomeranz, Munsell, & Harris, 2013; Rath, 2012).

A. SCOPE

This study is part of a larger project to investigate the association between sleep and symptom improvement in patients with MSK complaints. Under this general scope, this study has two goals. The first is to assess the prevalence of MSK symptoms in active duty personnel assigned to a U.S. Navy aircraft carrier. The second is to investigate the association between MSK symptoms, sleep amount, excessive daytime sleepiness, fatigue levels, and caffeinated beverage consumption.

II. METHODS

A. EQUIPMENT

A survey was developed that included demographic information and three standardized questionnaires. Questions included age, gender, rate/rank, height, weight, department in which the participant worked, whether the participant was a watch stander (and the watchstanding location), frequency of working out when deployed, use of sleep-promoting medication (either prescribed or over-the-counter), and the consumption of caffeinated beverages (specifically, the number of 8 ounces (oz.) cups of coffee, 12 oz. cans of caffeinated soft drinks, 8 oz. cups or glasses of hot or iced tea, and consumption of energy drinks). Using a 4-point Likert scale, participants indicated the adequacy of their sleep while at sea ("Much less than I need," "Less than I need," "About right," "More than I need," "Much more than I need"). Height and weight were measured and reported by the participant.

The Epworth Sleepiness Scale (ESS) was used to assess daytime sleepiness (Johns, 1991). The individual used a 4-item Likert scale to rate the chance of dozing off or falling asleep in eight different everyday situations. Scoring of the answers was 0 to 3, with 0 being "would never doze," 1 being "slight chance of dozing," 2 being "moderate chance of dozing," and 3 being a "high chance of dozing." Respondents were instructed to rate each item according to his/her usual way of life in recent times. Responses were summed to the total score. A score of 10 or more reflects above normal daytime sleepiness (Johns, 1992). The ESS questionnaire has a high level of internal consistency as measured by Cronbach's alpha, ranging from 0.73 to 0.88 (Johns, 1992).

To assess the nature and severity of self-rated MSK symptoms in nine body areas (neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs, knees, and ankles/feet), we used the revised version of the Nordic Musculoskeletal Questionnaire (NMQ-R) (Dickinson et al., 1992; Kuorinka et al., 1987). The NMQ-R asks respondents about MSK problems over the past week, over the past year, and whether MSK problems prevented them from carrying out their normal activities.

The Fatigue Severity Scale (FSS) was used to assess fatigue (Krupp, LaRocca, Muir-Nash, & Steinberg, 1989). The FSS is a self-reported, unidimensional questionnaire consisting of nine questions. Based on 7-point Likert scales for each question, individual item responses are averaged to give a total score; lower scores indicate less fatigue and higher scores indicate more fatigue. Krupp et al., in their 1989 paper, suggested a cut-off point of an FSS score ≥ 4 to identify elevated fatigue levels; however, this cut-off point has not received wide acceptance. Depending on the population, 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), whereas 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). In the original (1989) study by Krupp et al., the average score for a sample of normal subjects was 2.3 ± 0.7, whereas the average score for patients with systemic lupus erythematosus and multiple sclerosis was 4.7 ± 1.5 and 4.8 ± 1.3, respectively (Krupp et al., 1989).

B. PROCEDURES

This is a cross-sectional study using a survey tool. The study protocol was approved by the Naval Postgraduate School Institutional Review Board. All surveys were administered on the USS Nimitz in spring 2014, during the Body Composition Assessment (BCA) portion of the semiannual Physical Fitness Assessment (PFA).

Blank survey forms were offered to approximately 2,500 crewmembers as they presented for their height and weight measurement. A description of the study was posted at the check-in counter and medical department personnel were available to answer questions. Completed surveys were then collected in a box and were secured by medical staff. The overall response rate was approximately 30%.

C. PARTICIPANTS

We had 767 respondents with approximately a 30% response rate. Two-thirds of the sample was male. Average age was 25.4 ± 5.94 years, ranging from 18 to 49. Approximately 63% of the sample was watch standers. Participants were 2.74% officers (O-2 to O-5) and 93.6% enlisted personnel (34.2% E-1 to E-3, 55.5% E-4 to E-6, 3.31% E-7 to E-9, 6.99% missing data). Departmental response rate matched ship-wide personnel distribution with the exception of the Reactor Department, which was underrepresented (4.5% instead of 16%), and the Operations Department, which was over-represented (21.1% instead of 8.1%).

Participants' average BMI was 25.1 ± 3.34, ranging from 15.5 to 38.6. Based on their Body Mass Index (BMI), participants were classified as underweight (n=12, 1.88%), normal weight (n=310, 48.4%), overweight (n=2744, 2.8%), and obese (n=44, 6.88%). An overwhelming majority of respondents (90.4%) reported exercising an average of 3.98 ± 1.76 times per week (ranging from 0.5 to 12) when deployed.

D. 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 responses (0.37%) were interpolated for 22 participants, whereas 34 FSS responses (0.49%) were interpolated for 31 participants. Participants also reported their weekly consumption of drinks (i.e., coffee, caffeinated soft drinks, tea, and energy drinks).

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.

Participants were queried about MSK symptoms (aches, pain, discomfort, or numbness) and functional limitations due to symptoms. Prevalence data for the latest 12-month and 7-day periods of MSK symptoms were calculated for each one of the nine different anatomical sites in the NMQ-R. For the context of this study, prevalence was calculated as the number of responses (i.e., crewmembers) in the population sample of the USS Nimitz who have reported MSK symptoms.

Next, all variables underwent descriptive statistical analysis to identify anomalous entries and to determine demographic characteristics. Based on the reported consumption of caffeinated beverages and caffeine content of each bottle/can/cup (Clauson, Shields, McQueen, & Persad, 2003; Reissig et al., 2009), the approximate weekly caffeine intake was calculated using the following caffeine content per caffeinated beverage in this study. For our analysis we used the total caffeine content per caffeinated drink shown in Table 1.

Table 1. Total caffeine content per caffeinated drink in milligrams.

Caffeinated Beverage	**Total Caffeine (mg)**
Coffee (8 oz. cups)	100
Soft drinks (12 oz. cans)	35
Hot or iced tea (8 oz. cups or glasses)	30
Energy drinks	
Monster	160
Red Bull	80
Rock Star	160
NOS	250
5-Hour Energy	200
AMP	75
Sparks	170
No Fear	174

The preworkout supplements reported by two respondents were assumed to have 100 mg of caffeine per use.

To explore the association between sleep amount and caffeine (i.e., caffeinated drink use and estimated caffeine intake), classification trees were constructed based on recursive partitioning analysis (RPA). The latter is a robust method implementing a successive partitioning of a dataset into increasingly homogeneous subgroups, which does not require the assumptions of normality or homoscedasticity (Merkle & Shaffer, 2011; Zhang & Singer, 2010). The RPA program in JMP uses logworth ($\log_{10}$ of a weighted *p* value) to select split variables. Logworth values of 1.3 correspond to weighted *P* values of 0.05.

Stepwise multiple regression analysis (probability of entry = 0.05, removal = 0.10; second order interaction terms included) was used to explore independent predictors of dependent variables (i.e., nighttime sleep amount, ESS and FSS scores, dichotomous caffeinated beverage consumption, MSK symptoms in various anatomical sites). For the nighttime sleep amount, the variables selected for inclusion were age, BMI and BMI classifications, gender, watchstanding (Yes/No), frequency of workout, use of sleep-promoting medication, and consumption of caffeinated beverages. For the ESS and

FSS scores, the exploratory variables were age, BMI and BMI classifications, gender, watchstanding (Yes/No), frequency of workout, nighttime sleep amount, whether nighttime sleep was adequate, use of sleep-promoting medication, and consumption of caffeinated beverages. For the MSK symptoms in anatomical sites, the exploratory variables were age, BMI and BMI classifications, gender, watchstanding (Yes/No), frequency of workout, hours of nighttime sleep, whether nighttime sleep was adequate, use of sleep-promoting medication, consumption of caffeinated beverages, ESS score, and FSS score.

Statistical analysis was conducted with JMP statistical software (JMP Pro 10; SAS Institute; Cary, North Carolina). Results are presented as mean (M) ± standard deviation (SD) or median (MD) as appropriate. Significance level was set at $p < 0.05$. Wilcoxon Rank Sum test was used for comparisons.

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III. RESULTS

A. DESCRIPTIVE

Participants reported sleeping, on average, 6.12 ± 1.10 hours per night (range from 2.5 to 10) during the month prior to completing the survey. 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 (see Figure 1).

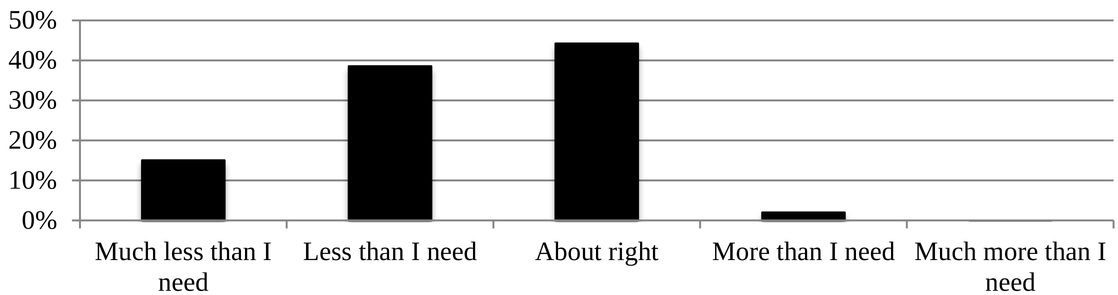

Figure 1. Responses to the statement "On average, when I am at sea my sleep amount is:"

Eighty-one participants (11.1%) reported using medications (prescription or over-the-counter) to help them sleep. The average ESS score was 8.41 ± 4.66, ranging from 0 to 24. ESS scores suggest that 237 participants (31.8%) had excessive daytime sleepiness (ESS score > 10) (Johns, 1991). Not surprisingly, participants with elevated ESS scores (> 10) reported sleeping less than participants with normal ESS scores (≤10) (ESS score ≤ 10: 6.24 ± 1.08 hours; ESS score > 10: 5.87 ± 1.09 hours; Wilcoxon Rank Sum test, $Z=4.49$, $p < 0.001$; $r=0.167$).

The average FSS score was 3.01 ± 1.37, ranging from 1 to 7. Assuming a cut-off point of FSS score ≥ 4, approximately 28% of the participants (n=204) would be classified as having elevated fatigue levels. Using a cut-off point of FSS score ≥ 5, 9% of the participants (n=65) would be classified as having elevated fatigue levels. A correlation analysis (Spearman's rho) among age, BMI, weekly frequency of workout, hours of sleep, and ESS and FSS scores showed that the FSS scores were positively correlated with age and ESS scores, and negatively correlated with the frequency of working out and sleep amount (see Table 2).

Table 2. Correlation matrix of demographics, exercise, sleep, and fatigue.

	BMI	**Frequency Working Out**	**Sleep Amount**	**ESS Total Score**	**FSS Score**
Age	0.20***				0.15***
BMI		0.19***			
Frequency working out					–0.21***
Sleep amount				–0.17***	–0.16***
ESS Total Score					0.39***

Inclusion criterion $p < 0.10$; *** $p < 0.001$

B. CONSUMPTION OF CAFFEINATED BEVERAGES

A large percentage (88.3%) of the participants reported consuming at least one type of caffeinated beverage. Coffee and caffeinated soft drinks were most often consumed (> 50% of the responses), followed by energy drinks (~ 35% of the responses) and tea (~ 35% of the responses). Of those individuals using energy drinks, the most common brand reported was Monster (n=198, 72.5%), followed by Red Bull (n=52, 19.1%). Preworkout supplements were included in the energy drink data. Figure 2 shows these results.

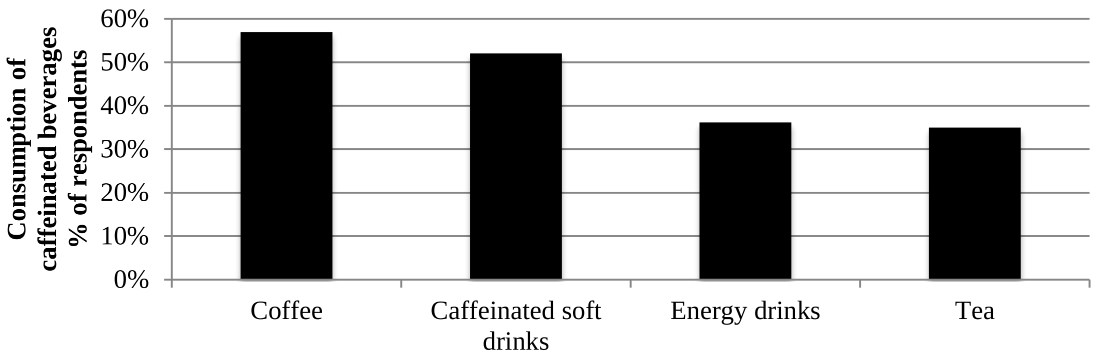

Figure 2. Percentages of respondents reporting consumption of caffeinated beverages.

It is notable that some participants reported drinking excessive amounts of caffeine: up to 90 cups of coffee and 30 energy drinks per week. These results are shown in Table 3.

Table 3. Reported consumption of caffeinated beverages on a weekly basis.

Caffeinated Beverage	M ± SD	Median	Minimum	Maximum
Coffee (8 oz. cups)	7.06 ± 9.05	5	1.0	90
Caffeinated Soft Drinks (12 oz. cans)	4.63 ± 5.08	3	0.5	48
Hot or Iced Tea (8 oz. cups or glasses)	4.15 ± 4.83	3	1.0	40
Energy Drinks (#)	3.79 ± 3.50	3	1.0	30

Next, we conducted a statistical partition analysis to explore the association between sleep amount and weekly caffeine intake. As depicted in Figure 3, partition results showed that crewmembers receiving more than 1,270 mg of caffeine weekly (approximately 180 mg daily) reported sleeping, on average, 5.79 ± 1.17 hours. In contrast, crewmembers receiving less than 1,270 mg of caffeine weekly reported sleeping, on average, 6.17 ± 1.07 hours. The Wilcoxon rank sum test showed significant differences in reported sleep duration between the two caffeine categories ($Z=3.62$, $p < 0.001$, $r=0.135$).

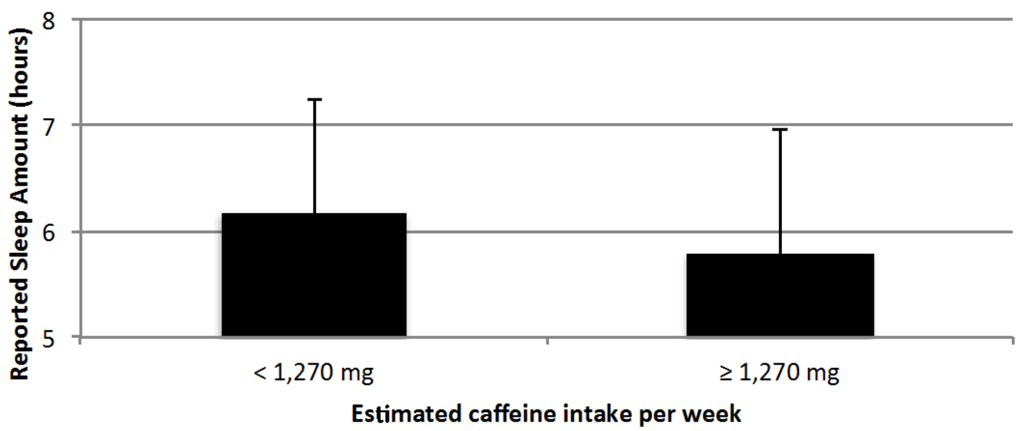

Figure 3. Sleep amount by caffeine intake category.

C. MUSCULOSKELETAL SYMPTOMS

Overall, 423 respondents (57.5%) reported experiencing at least one MSK symptom during the previous 12 months; 327 respondents (44.4%) reported at least one symptom during the previous week, while 150 respondents (20.4%) reported that at least one MSK problem prevented them from carrying out their normal activities. Table 4 and Figure 4 show the prevalence of reported MSK symptoms during the last 12 months and the last 7 days. They also show the prevalence of MSK problems preventing participants from carrying out their normal activities. The two anatomical sites most frequently reported for both MSK symptoms and preventing participants from carrying out normal activities were the lower back and knees.

Table 4. Prevalence of reported MSK symptoms.

Anatomical Sites Affected	Occurrence During the Last 12 Months # (%)	Occurrence During the Last 7 Days # (%)	Occurrence of MS Symptoms Preventing Crewmembers From Carrying Out Normal Activities # (%)
Neck	193 (26.20%)	126 (17.20%)	30 (4.09%)
Shoulders	220 (29.90%)	128 (17.40%)	38 (5.18%)
Elbows	60 (8.25%)	27 (3.71%)	9 (1.23%)
Wrist/hands	158 (21.60%)	75 (10.30%)	29 (3.95%)
Upper back	152 (20.80%)	88 (12.10%)	22 (3.00%)
Lower back	291 (39.50%)	199 (27.10%)	74 (10.10%)
Hips/thighs	112 (15.03%)	61 (8.35%)	17 (2.33%)
Knees	246 (33.60%)	166 (22.60%)	58 (7.90%)
Ankles/feet	177 (24.30%)	109 (15.00%)	43 (5.90%)

refers to the number of respondents

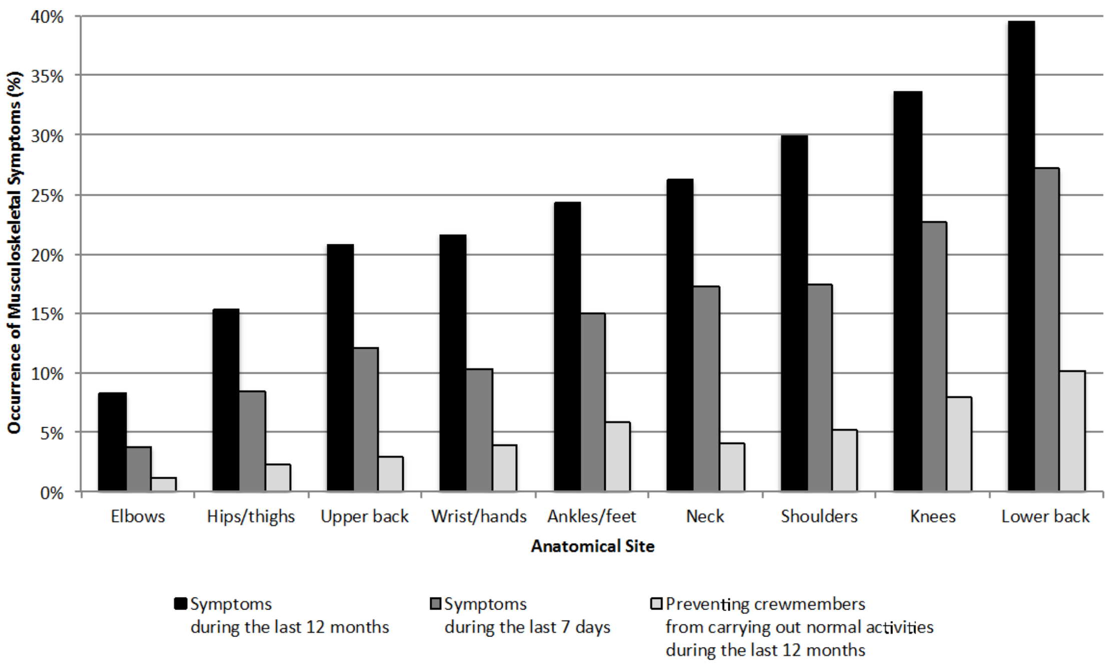

Figure 4. Prevalence of reported MSK symptoms by anatomical site.

By anatomical site, we also calculated the relative percentage of respondents with an MSK symptom that prevented them from daily activities in the last 12 months. For example, from the 177 respondents with ankles/feet symptoms during the last 12 months, 43 (24.3%) reported that these symptoms prevented them from carrying out normal activities. Results showed that individuals with symptoms in ankles/feet, knees, and lower back were more often prevented in their daily activities by these MSK symptoms (see Figure 5).

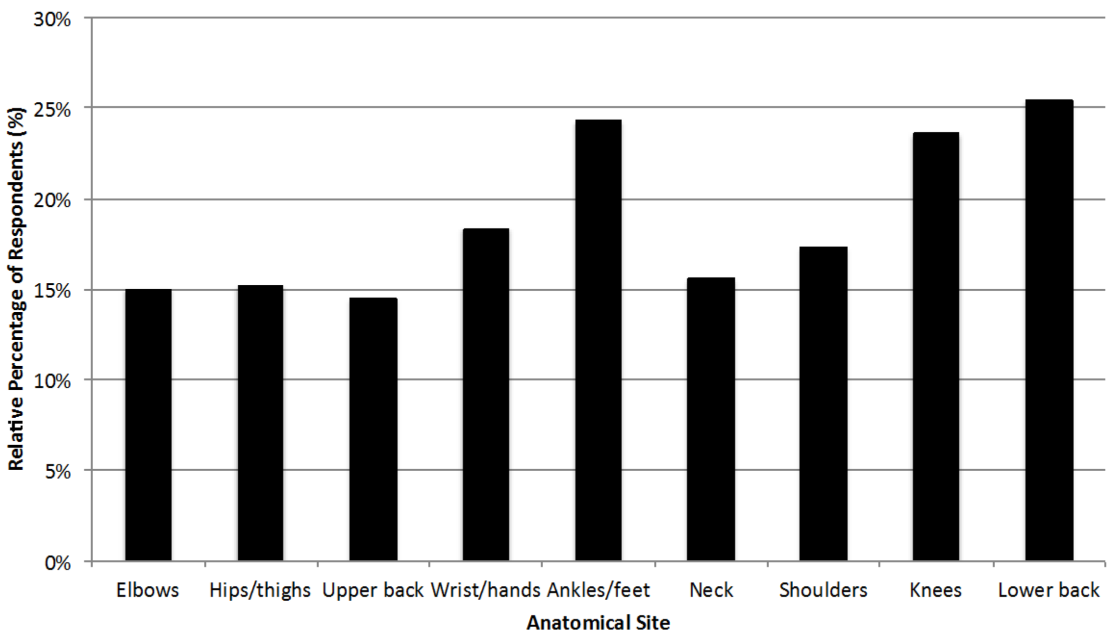

Figure 5. Relative percentage of MSK symptoms by anatomical site.

A relatively large proportion of respondents indicated experiencing symptoms in more than one MSK site. Approximately34% of the respondents reported having MSK problems in more than three of the nine anatomical sites during the last 12 months, whereas 22% of the respondents reported having MSK problems in more than three of the nine anatomical sites during the last 7 days.

D. PREDICTOR MODELS

1. Sleep Amount

A stepwise multivariate regression analysis included five significant predictors for sleep amount: gender (p=0.007; females sleep less than males); watchstanding (p < 0.001; watchstanders sleep less than nonwatchstanders); BMI (p=0.028; increased BMI was associated with less sleep); workout frequency (p=0.028; increased frequency was associated with more sleep); consumption of energy drinks (p < 0.001; nondrinkers sleeping more than drinkers); and five interaction terms (overall model: R^2adjusted = 0.076, F(12,475)=4.32, p < 0.001). These results are presented in Table 5.

Table 5. Predictor variables for sleep amount.

Predictor Variables	**Coefficient**	**Beta Value**[1]	**P Value**
Gender [Females]	–0.198	–0.182	0.007
Watchstanding [Yes]	–0.270	0.256	< 0.001
BMI	–0.033	–0.110	0.027
Workout frequency	0.052	0.106	0.028
Energy drinks consumption [Yes]	–0.198	–0.184	0.009
Gender [Female] * Sleep medications [Yes]	–0.188	–0.174	0.009
Watch standing [Yes] * Sleep medications [Yes]	–0.211	–0.202	0.004
BMI * Workout frequency	–0.015	–0.101	0.026
BMI * Energy drinks consumption [Yes]	–0.034	–0.114	0.020
Workout frequency * Energy drinks consumption [Yes]	0.057	0.118	0.013

[1] Measured in units of standard deviation, the beta value assesses the strength of the association between a predictor variable and sleep amount (i.e., the higher the beta value, the greater the impact of the predictor variable). In a model with only one predictor variable, the beta is equivalent to the correlation coefficient.

2. ESS and FSS Scores Stepwise Analysis

A stepwise multivariate regression analysis identified that sleep amount (p=0.054), and the evaluation of sleep adequacy at sea (“Much more than needed + More than needed + About right” versus “Much less than needed + Less than needed”) (p < 0.001) were predictors of ESS scores (overall model: R^2 adjusted=0.059, F(2,710)=23.4, p < 0.001).

The stepwise multivariate regression analysis also identified the following as significant predictors of FSS scores (overall model: R^2 adjusted=0.162, F(6,598)=20.5, p < 0.001): age (p < 0.001), workout frequency (p < 0.001), sleep amount (p < 0.005), and sleep adequacy at sea—“Much more than needed + More than needed + About right” versus “Much less than needed + Less than needed” (p < 0.001) and “Much less than needed” versus “Less than needed” (p < 0.001). A statistically significant interaction was also found between age and sleep amount (p=0.018). These results are presented in Table 6.

Table 6. Predictor variables for the ESS and FSS scores.

Predictor Variables	Coefficient	Beta	P value
ESS			
Nighttime sleep amount	–0.617	–0.146	< 0.001
Sleep amount adequacy at sea (Much more + More + About right + Less versus Much less)	–1.13	–0.176	< 0.001
FSS			
Age	0.029	0.127	< 0.001
Workout frequency	–0.129	–0.193	< 0.001
Nighttime sleep amount	–0.141	–0.110	0.005
Sleep amount adequacy at sea			
“Much more + More + About right” versus “Much less + Less”	–0.371	–0.268	< 0.001
“Much less” versus “Less”	–0.284	–0.144	< 0.001
Age * Nighttime sleep amount	–0.020	–0.089	0.018

3. Stepwise Analysis of MSK Data

Tables 7 to 8 show the R^2 and the parameter estimates for the predictor variables for each of the nominal logistic models. As appropriate, an effect size was calculated for each predictor factor included in the models: the odds ratios (OR) with the corresponding 95% confidence intervals (CI) (OR [95% CI]) are used for categorical variables, while nonparametric correlations, based on Spearman’s rho, are used for continuous variables. For example, in the model predicting 12-month occurrence of neck symptoms, the use of sleep-promoting medication is included in the model with $p < 0.01$. The parameter estimate for this factor is 0.359, whereas the OR for having MSK symptoms without receiving sleep medication is 2.05 with a 95% CI between 1.21 and 3.45.Overall, analysis results suggest the following interesting points:

- Females report more MSK symptoms than males.
- Participants with MSK symptoms are, in some cases, more likely to consume caffeinated beverages. To further investigate this pattern of results, we assessed whether participants with MSK symptoms use at least one type of the caffeinated beverages. Results showed that participants with MSK symptoms in the past 12 months are more likely to use at least one type of the caffeinated beverages (Fisher’s exact test, p=0.046; Odds ratio = 1.61 [1.01 – 2.56]).
- Older crewmembers are more likely to report MSK symptoms.

- Crewmembers reporting MSK symptoms in the last 12 months are more likely to use sleep-promoting medications.
- Crewmembers with MSK symptoms show increased daytime sleepiness and increased levels of fatigue compared to crewmembers without MSK symptoms.
- Watchstanding, BMI, workout frequency, and energy drinks were not associated with MSK symptoms in this population sample.

Based on these results, we explored the association between ESS/FSS scores and symptom occurrence in at least one MSK site. Respondents with a symptom in at least one MSK site in the last 12 months had ESS scores that were, on average, 16% higher than those who reported no symptoms (Symptomatic ESS score=8.97 ± 4.60; Asymptomatic ESS score=7.75 ± 4.63; Wilcoxon Rank Sum test, Z=3.38, $p < 0.001$; r=0.125). The same trend was identified in respondents with a symptom in at least one MSK site in the last seven days (Δ=23%; Symptomatic ESS score=9.50 ± 4.63; Asymptomatic ESS score=7.70 ± 4.53; Wilcoxon Rank Sum test, Z=5.16, $p < 0.001$; r=0.191); respondents reporting that an MSK symptom in at least one MSK site prevented normal activities in the last 12 months (Δ=21%; Symptomatic ESS score=9.84 ± 5.30; Asymptomatic ESS score=8.12 ± 4.46; Wilcoxon Rank Sum test, Z=3.53, $p < 0.001$; r=0.131).

Participants with MSK symptoms also reported increased FSS scores compared to participants without MSK symptoms. Individuals reporting at least one MSK symptom in the past 12 months had FSS scores that were on average 27% higher than those who reported no symptoms (symptomatic: FSS score=3.32 ± 1.33; asymptomatic: FSS score=2.61 ± 1.30; Wilcoxon Rank Sum test, Z=7.0, $p < 0.001$; r=0.261). This phenomenon was also identified in participants reporting the occurrence of MSK symptoms occurring in the last seven days (Δ=29%; Symptomatic FSS score=3.47 ± 1.36; Asymptomatic FSS score=2.70 ± 1.29; Wilcoxon Rank Sum test, Z=7.40, $p < 0.001$; r=0.276); and in participants reporting the MSK symptoms prevented normal activities in the last 12 months (Δ=25%; Symptomatic: FSS score=3.63 ± 1.38; Asymptomatic FSS score=2.88 ± 1.33; Wilcoxon Rank Sum test, Z=5.42, $p < 0.001$; r=0.202). These results are shown in Figures 6 and 7. Tables 7 and 8 show in detail the predictor variables for the 12-month and 7-day MSK symptoms by anatomical site.

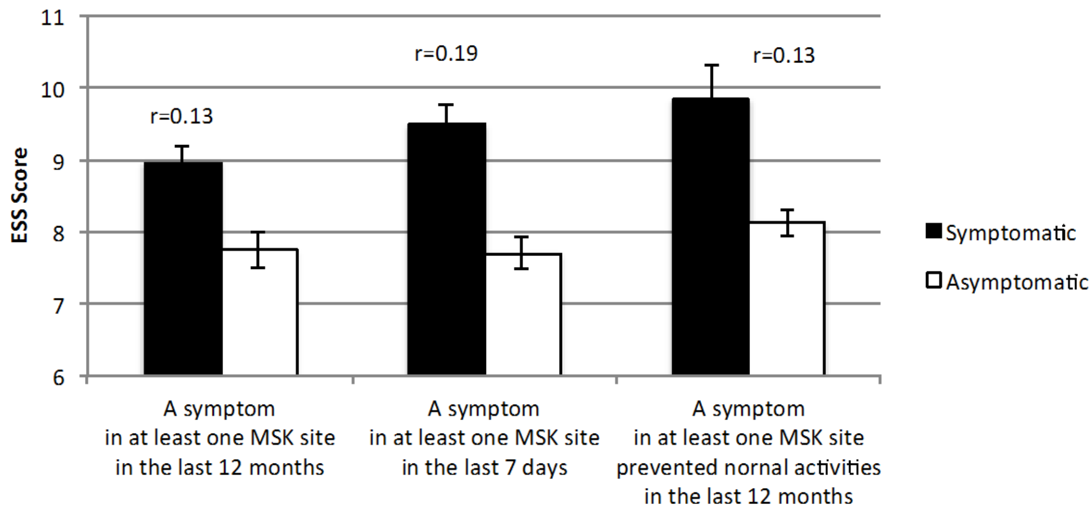

Figure 6. ESS scores versus occurrence of MSK symptoms. Vertical bars denote the Standard Error of the Mean. Labels denote effect size r.

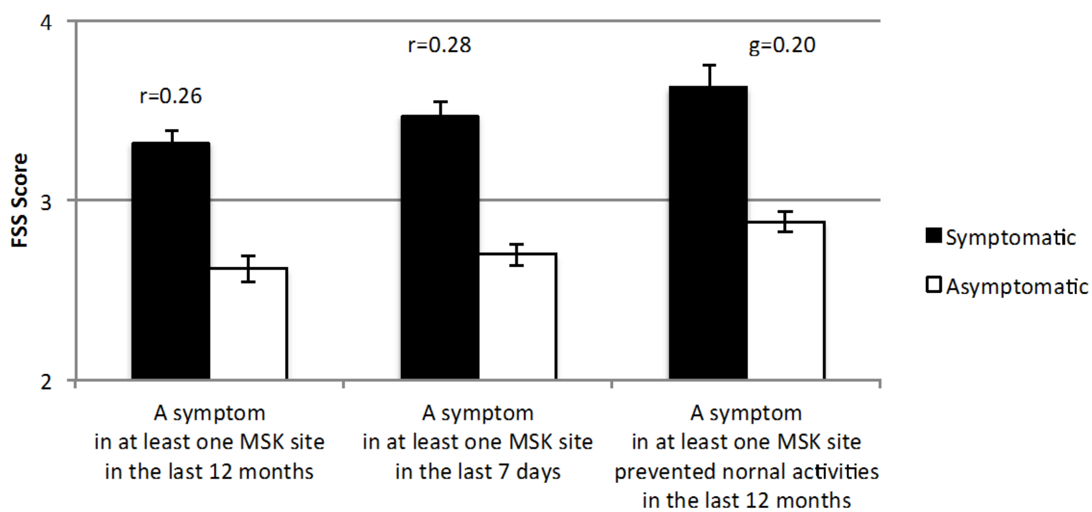

Figure 7. FSS scores versus occurrence of MSK symptoms. Vertical bars denote the Standard Error of the Mean. Effect size r is listed top of column.

Table 7. Predictors of 12-month MSK symptoms in anatomical sites.

Variables	Upper Extremity Area Elbows R^2=0.041	 Wrist/Hands R^2=0.120	Upper Body Area Neck R^2=0.103	 Shoulders R^2=0.129	 Upper Back R^2=0.087	Lower Back R^2=0.115	Hips R^2=0.100	Lower Extremity Area Knees R^2=0.066	 Ankles R^2=0.070	At Least One MSK Symptom R^2=0.194
Gender [female]	-	-	0.286** 1.77 [1.22-2.58]	0.401*** 2.23 [1.53-3.27]	0.416*** 2.30 [1.55-3.41]	0.433*** 2.38 [1.69-3.41]	-	0.427*** 2.35 [1.65-3.35]	-	0.450 ***
Watchstanding	-	-	-	-	-	-	-	-	-	-
Age	-	-	-	0.062***		0.053***	0.056***	0.069***	-	0.067 *** rho=0.141***
BMI	-	-	-	-	-	-	-	-	-	-
Workout frequency	-	-	-	-	-	-	-	-	-	-
Sleep amount	-	-	-	–0.284***	-	-	-	-	–0.239**	–0.242 ** rho=–0.198***
Adequacy of sleep at sea	-	-	0.318**	-	-	0.509*** -	-	0.458*** -	-	0.419 **
Sleep medication [Yes]	-	0.352* 2.02 [1.16-3.48]	0.359** 2.05 [1.21-3.45]	-	-	-	0.564*** 3.09 [1.74-5.38]	-	-	0.310 *
Consumption										
Coffee [Yes]	-	0.354*** 2.0 [1.35-3.08]	0.223* 1.56 [1.08-2.28]	0.298** 1.81 [1.25-2.64]	0.187 1.45 [0.98-2.18]	-	-	-	-	-
Caffeinated soft drinks [Yes]	-	-	-	-	-	0.276** 1.74 [1.24-2.44]	-	0.235** 1.60 [1.15-2.24]	-	-
Tea [Yes]	0.332* 1.94 [1.12-3.36]	-	-	-	-	-	-	-	-	-
Energy drinks	-	-	-	-	-	-	-	-	-	-
ESS	-	-	0.061**	-	0.063**	-	-	-		-
FSS	0.323**	0.591***	0.304***	0.415***	0.318***	0.339***	0.428***	-	0.374***	0.515 *** rho=0.324 ***

Table inclusion criterion: $p < 0.10$

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Sleep amount adequacy at sea (Much more + More + About right + Less versus Much less)

Table 8. Predictors of 7-day MSK symptoms in anatomical sites.

Variables	Upper Extremity Area		Upper Body Area			Lower Back	Hips	Lower Extremity Area		At Least One MS Symptom
	Elbows	Wrist/Hands	Neck	Shoulders	Upper Back			Knees	Ankles	
	R^2=0.044	R^2=0.043	R^2=0.105	R^2=0.099	R^2=0.111	R^2=0.086	R^2=0.097	R^2=0.095	R^2=0.074	R^2=0.195
Gender [Female]	-	-	–0.362 ** 2.06 [1.32-3.22]	-	0.520 *** 2.83 [1.71-2.60]	0.332 *** 1.94 [1.35-2.80]	-	0.341 ** 1.96 [1.32-2.97]	-	0.372 ***
Watchstanding	-	-	-	-	-	-	-	-	-	-
Age	-	-	0.035 *	0.040 *	0.056 **	-	0.071 ***	0.057 ***	-	0.057 *** rho=0.118 **
BMI	-	-	-	-	-	-	-	-	-	-
Workout frequency	-	-	-	-	-	-	-	-	-	-
Sleep amount	-	-	-	-	–0.307 **	-	-	-	–0.249 *	–0.175 ** rho=-0.196***
Adequacy of sleep at sea	-	-	-	-	-	-	-	-	-	-
Sleep medication [Yes]	-	-	-	-	-	-	0.416 * 2.30 [1.11-4.52]	-	-	-
Consumption										
Coffee [Yes]	-	-	-	0.205 1.51 [0.97-2.37]	0.212 1.53 [0.92-2.60]	-	-	-	-	-
Caffeinated soft drinks [Yes]	-	-	-	-	-	0.252 ** 1.66 [1.16-2.38]	-	0.280 ** 1.75 [1.19-2.59]	-	0.119
Tea [Yes]	-	-	-	-	-	-	-	0.207 * 1.51 [1.03-2.22]	-	-
Energy drinks [Yes]	-	-	-	-	-	-	-	-	-	-
ESS	0.131 **	-	0.062 *	0.067 **	-	0.056 **	-	0.062 **		0.062 *** rho=0.228 ***
FSS	-	0.328 ***	0.395 ***	0.370 ***	-	0.337 ***	0.415 ***	0.244 **	0.437 ***	0.315 *** rho=0.313 ***

Table inclusion criterion: $p < 0.10$

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

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IV. DISCUSSION

Results show that the sample of active duty personnel slept approximately six hours per night; considerably less than the 8-hour level recommended by sleep experts. This sleep duration is comparable to previous findings from crewmembers aboard other U.S. Navy ships (Miller et al., 2012). Consequently, it was no surprise that more than 50% of the participating crewmembers rated their sleep as less than needed and 31.8% have excessive daytime sleepiness as indicated by ESS scores of greater than 10.

As assessed by the FSS scores, fatigue levels in the USS Nimitz sample (3.01 ± 1.37) were comparable to the FSS scores of healthy subjects (3.01 ± 1.08) in the study by Valko et al. (2008), but were higher than the FSS scores of normal subjects (2.3 ± 0.7) in the study by Krupp et al. (1989). The average FSS scores in the USS Nimitz sample were less than scores of patients with systemic lupus erythematosus (4.7 ± 1.5) and multiple sclerosis (4.8 ± 1.3) (Krupp et al., 1989), patients with multiple sclerosis (4.66 ± 1.64), patients after ischemic stroke (3.90 ± 1.85), and patients with sleep-wake disorders (4.34 ± 1.64) (Valko et al., 2008). Assuming a cut-off point of FSS score ≥ 5, approximately 9% of the participants would be considered as having increased fatigue, less than the 23.1% prevalence found in a Norwegian population (Lerdal, Wahl, Rustoen, Hanestad, & Moum, 2005).

Approximately 58% of the respondents indicated having at least one MSK symptom in the last 12 months; 44% indicated having at least one symptom in the last 7 days; and 20.4% indicated that MSK symptoms had prevented participants from carrying out their normal activities including their work. The 12-month prevalence is lower than a sample of oil and gas industry personnel (80%), but higher than the corresponding 7-day prevalence of 37% (Parks et al., 2005).

The two anatomical sites most frequently reported for both MSK symptoms and for preventing participants from carrying out normal activities were the lower back (39.5% 12-month prevalence) and knees (33.6% 12-month prevalence). The site least reported was the elbow (8.25% 12-month prevalence). The prevalence of lower back problems is consistent with findings from other studies (Parks et al., 2005), but the 12-month prevalence in our sample is lower than the 51% prevalence rate reported by oil and gas industry personnel (Parks et al., 2005), the 50% prevalence found in a study focused on the Danish population in conjunction with four surveys conducted in the Nordic countries (Leboeuf Yde, Klougart, & Lauritzen, 1996), the 73% value found in sewage workers (Friedrich, Cermak, & Heiller, 2000), and the 73% to 76% identified in a sample of Swiss nurses (Maul, Laubli, Klipstein, & Krueger, 2003).

Another interesting finding was that individuals reporting MSK symptoms in ankles/feet (24.3%), knees (23.6%), and lower back (25.4%) were more often prevented from carrying out their daily activities as compared to other anatomical sites.

As expected from earlier research (for example, Bergqvist et al., 1995), we verified that age is associated with the occurrence of MSK symptoms. Specifically, results from this study support the notion that older crewmembers are more likely to report MSK symptoms. Furthermore, females reported more MSK symptoms compared to males. In general, research findings suggest that women are more apt to report intensity, number, and frequency of bodily symptoms than men. Some researchers have attributed this finding to a female tendency to report MSK symptoms rather than an actual difference in MSK development (Almeida et al., 1999; Barsky, Peekna, & Borus, 2001; Cole, Ibrahim, Shannon, Scott, & Eyles, 2001; Korhonen et al., 2003).

The most interesting finding of this study is the association of MSK symptoms with elevated fatigue (g=0.54 – 0.59) and with elevated daytime sleepiness (g=0.26 – 0.39) levels. Crewmembers with MSK symptoms are also more likely to use sleep-promoting medications, compared to crewmembers without MSK symptoms. Given their elevated levels of sleepiness, it is no surprise that crewmembers with MSK symptoms are more likely to consume caffeinated beverages (coffee, soft drinks, and tea, but not energy drinks). Overall, 88.3% of all respondents reported using at least one type of caffeinated beverage; coffee was used by approximately 55%, followed by soft drinks (~ 50%), energy drinks (~ 35%) and tea (~ 35%). Notably, the maximum reported consumption by one participant was 90 cups of coffee and 30 energy drinks per week. Overall, the consumption of energy drinks was 10% less than U.S. service members in combat conditions in Afghanistan (Havenetidis & Paxinos, 2011).

Crewmembers who received more than 1,270 mg of caffeine weekly (equivalent to 180 mg daily) slept less than crewmembers who received less than 1,270 mg of caffeine. An earlier study assessed sleep problems and energy drink consumption among U.S. service members on a combat deployment in Afghanistan (Toblin et al., 2012). Results from this study showed that service members who drank three or more energy drinks per day were more likely to report less than, or equal to, four hours of sleep, on average, per night (38.2%) than service members who drank one to two (18.4%) or zero (23.9%) energy drinks per day.

Results also show that 42.7% of respondents were overweight and 7% obese. The obesity findings, however, are better than the average U.S. population; according to data from the 1999-2000 National Health and Nutrition Examination Survey (NHANES), approximately 64% of adults 20 years old and over are either overweight or obese (Center for Disease Control and Prevention [CDC], 2003). Compared to a large epidemiological study of aircraft carrier personnel data from 2008 (Jones, Cowan, & Knapik, 1994), approximately 50% of our sample had weight above normal (compared to 63%), and the prevalence of obese participants was half (7% compared to 15%). In contrast to other studies (Gregg & Jankosky, 2012), we did not identify an association between MSK complaints and BMI. Perhaps this nonfinding shows the limits of using BMI to assess adiposity in military populations. This phenomenon was also identified in a study conducted at the Hellenic Army Academy, which used both BMI and body fat percentage (BFP) (Moreira-Silva, Santos, Abreu, & Mota, 2013; Viester et al., 2013). Results from the latter study showed that MSK symptoms were associated with BFP, but not BMI.

Lastly, approximately 50% of the respondents indicated working out an average of four or more times per week. The percentage of crewmembers working out three or more times per week was 72%, compared to 65% reported by 5,565 sailors in the 2014 Navy Retention Study (Snodgrass & Kohlmann, 2014). Unexpectedly, however, the occurrence of MSK symptoms was not associated with the frequency of workout. Other studies have shown that MSK symptoms are common among individuals engaging in exercise programs that include running activities (Almeida et al., 1999). In general, greater duration and frequency of exercise are associated with higher risks of injury (Jones et al., 1994).

A. STUDY LIMITATIONS

This study has a number of limitations. In terms of generalizability, the sample size is relatively small, representing only 30% of the ship's crew. In addition, data were collected from one aircraft carrier toward the end of an extended deployment and, consequently, may not be representative of other U.S. Navy carrier populations. Like other U.S. Navy service members, however, the population onboard is screened and selected specifically for duty at sea. As such, the population is younger than the general U.S. population and the prevalence of chronic disease is assumed to be lower.

This cross-sectional study used a survey instrument in which respondents self-reported their history of MSK symptoms, fatigue, sleepiness, and sleep adequacy. Such an epidemiological study has a number of constraints, e.g., associations cannot be interpreted as causal, results are not easily generalizable, etc. A cross-sectional study, however, can provide useful insight regarding the population and is generally accepted by most researchers (Toblin et al., 2012). MSK complaints were retrospectively assessed. Even though retrospective reports on MSK pain intensity are, in general, reliable (Brauer, Thomsen, Loft, & Mikkelsen, 2003), future efforts should investigate MSK prevalence using more accurate methods (David, 2005).

Although height and weight were objectively measured, the use of BMI to assess obesity is also a concern. The calculation of BMI in athletic individuals with high muscle mass may overestimate obesity prevalence (Punnett & Wegman, 2004); however, it has also been reported that BMI may underestimate the prevalence of obesity (Rothman, 2008). Future investigations should assess adiposity with metrics other than BMI (Alasagheirin, Clark, Ramsey, & Grueskin, 2011).

B. FUTURE RESEARCH

Future studies should attempt to establish criteria for adequate sleep in this population (sleep quantity and quality to ensure normal function and healing) and to evaluate causality between lack of adequate sleep and poor healing (incomplete or slow recovery from MSK injury).

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