Caffeinated Beverage Consumption Rates and Reported Sleep in a United States Navy Ship

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Ship crews live and work in an environment characterized by extreme sleep deprivation. In an attempt to maintain alertness, crewmembers frequently consume caffeinated beverages and energy drinks. As part of a broader study, this work assesses the consumption of caffeinated beverages and investigates the association between caffeinated beverage consumption and reported sleep amount. Crewmembers of a U.S. Navy aircraft carrier (N=767; age 18-49 years) completed a survey with questions pertaining to demographics, exercise frequency, average sleep duration, caffeine beverage consumption, the Epworth Sleepiness Scale (ESS), and the Fatigue Severity Scale (FSS). Results show that the sample of active duty personnel slept approximately six hours per night. Most respondents (~90%) reported using at least one type of caffeinated beverage (~55% coffee, ~50% soft drinks, ~35% energy drinks, and ~35% tea). The participants who reported drinking caffeinated drinks had an average weekly caffeine intake of 812±917 mg (MD=540), ranging from 30 to 9210 mg. Crewmembers who consumed more than 1,270 mg of caffeine weekly (equivalent to 180 mg daily) reported sleeping 5.79±1.17 hours, whereas crewmembers that drank less than 1,270 mg of caffeine reported sleeping 6.17±1.07 hours ($p<0.001$). Overall, our study shows widespread use of caffeine among active duty crewmembers in our sample. Our results suggest that caffeine intake -- in the form of coffee, tea, caffeinated soft drinks, or energy drinks – is associated with sleep and may interfere with sleep patterns while working at sea. Future efforts should be directed at exploring causal relationships involved in this phenomenon. Better understanding of causal links will enable appropriate guidance for better sleep hygiene in the maritime operational environment.

INTRODUCTION

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 frequently consume caffeinated beverages and energy drinks. 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 close to a major sleep period, may also interfere with sleep.

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). Marketed to improve energy, stamina, athletic performance, and concentration, energy drinks may also contain caffeine, taurine, sugar or sweeteners, and vitamins (Seifert, Schaechter, Hershorin, & Lipshultz, 2011). 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 improved mood (Smit & Rogers, 2002).

Recent studies show 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. Interestingly, approximately 56% of officers and 85% of all enlisted active duty personnel in the U.S. armed forces belong to the major demographic age groups for the marketing of energy drinks ("2012 Demographics: Profile of the Military Community," 2014; Heckman, Sherry, & Gonzalez de Mejia, 2010).

Given the concerns about the use of energy drinks, this study has two goals. The first is to assess the rate of consumption of caffeinated beverages in active duty personnel assigned to a US Navy aircraft carrier. The second is to investigate the association between caffeinated beverage consumption and reported sleep amount. This study is part of a broader assessment of the prevalence of musculoskeletal symptoms in active duty personnel (Shattuck, Matsangas, Moore, & Wegemann, 2015).

METHODS

Equipment

The current analysis includes information on age, gender, height, weight, whether the participant was a watch stander, frequency of working out when deployed, use of sleep-promoting medication (either prescribed or over-the-counter), and the weekly 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). Using a 4-item Likert scale, individuals rated their 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 "high chance of dozing." Respondents were instructed to rate each item according to his/her usual way of life in recent time. Responses were summed to derive 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).

Procedures

This cross-sectional study used a survey. The study protocol was approved by the Naval Postgraduate School Institutional Review Board. All surveys were administered to crewmembers of 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 the medical staff. The overall response rate was approximately 30%. As part of a larger study, the survey included additional information that is not included in this work.

Analytical Approach

The Body Mass Index (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 = BMI less than 18.50 kg/m^2, normal BMI = 18.50 to 24.99 kg/m^{2,} overweight BMI = 25 to 29.99 kg/m^2, and obese BMI = more than 30 kg/m^2.

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 caffeine content per caffeinated drink shown in Table 1.

Table 1. Total caffeine content per caffeinated drink in milligrams (mg)

Caffeinated beverage	Caffeine (mg)
Coffee (8 oz. cups)	100
Soft drinks (12 oz. cans)	35
Hot or iced tea (8 oz. cups/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

To explore the association between reported sleep duration and weekly caffeine consumption, a classification tree was constructed based on recursive partitioning analysis (RPA). RPA is a robust statistical method involving successive partitioning of a dataset into increasingly homogeneous subgroups. RPA does not require the assumptions of normality or homoscedasticity (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. The weekly caffeine consumption of each respondent was calculated by multiplying the reported number of caffeinated beverages and energy drinks with the corresponding caffeine content in each bottle/can/cup (Clauson et al., 2003; Reissig et al., 2009). Based on the weekly caffeine consumption, participants were classified into three groups, "Low" when caffeine intake was less than 250 mg per day, "Moderate" when caffeine intake ranged between 250 and 750 mg per day, and "High" when caffeine intake was more than 750 mg per day (Winston, Hardwick, & Jaberi, 2005).

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.

RESULTS

We had 767 respondents with an approximate 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 were watch standers. Participants included 2.74% officers and 93.6% enlisted personnel (6.99% missing data). Departmental response rate matched ship-wide personnel distribution with the exception of the Reactor Department, which was under-represented (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 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.

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. 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 reported sleeping less than participants with normal ESS scores (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).

A correlation analysis (Spearman's rho) among age, BMI, weekly frequency of workout, hours of sleep, and ESS scores showed that age was correlated with BMI (rho = 0.20, $p < 0.001$), BMI was correlated with workout frequency (rho = 0.19, $p < 0.001$), and reported sleep duration was correlated with ESS scores (rho = -0.17, $p < 0.001$).

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%). Figure 1 shows these results.

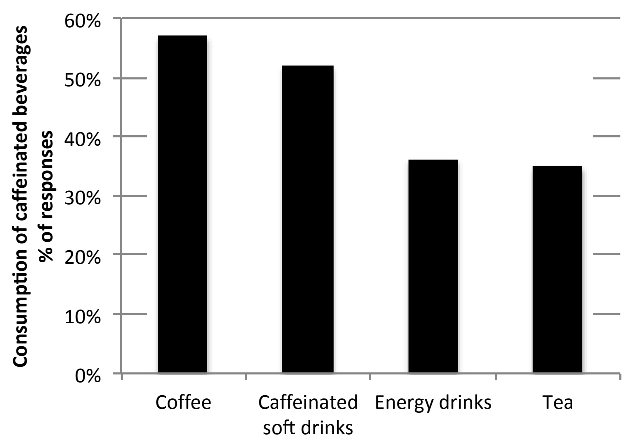

Figure 1. Percentages of respondents reporting consumption of caffeinated beverages.

Table 2 shows the consumption of caffeinated beverages by type. For example, for those participants who reported drinking coffee, the average weekly consumption was 7.06 8-oz. cups. It is notable that some participants reported drinking excessive amounts of caffeine: up to 90 cups of coffee and 30 energy drinks per week.

Table 2. Reported consumption of caffeinated beverages on a weekly basis.

Caffeinated Beverage	M ± SD	MD	Min	Max
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

Based on the reported weekly consumption of caffeinated beverages, we calculated the approximate weekly caffeine intake for each participant. For those participants who reported drinking caffeinated drinks, the average weekly consumption was 812 ± 917 mg (MD = 540), ranging from 30 to 9210 mg. Based on their daily consumption, approximately 10% of caffeine drinkers were included in the Moderate and High Caffeine intake groups.

Next, we conducted a statistical partition analysis to explore the association between the reported sleep amount and the calculated weekly caffeine intake. 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). These results are shown in Figure 2.

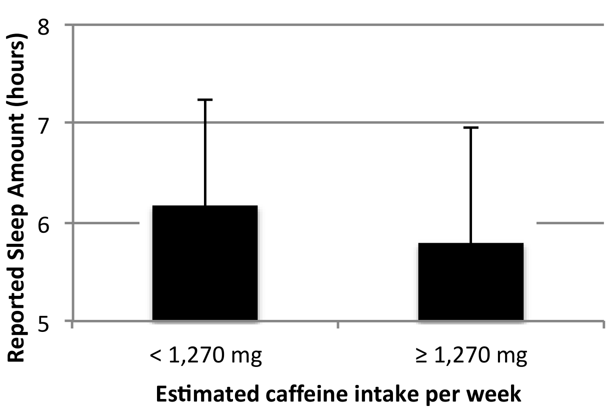

Figure 2. Sleep amount by caffeine intake category.

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 non-watchstanders); BMI (p=0.028; increased BMI was associated with less sleep); workout frequency (p=0.028; increased workout frequency was associated with more sleep); consumption of energy drinks ($p < 0.001$; non-drinkers sleep 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 3.

Table 3. Predictor variables for reported sleep amount

Predictor Variables	Beta	*P* Value
Gender [F]	–0.182	0.007
Watchstanding [Yes]	-0.256	< 0.001
BMI	–0.110	0.027
Workout frequency	0.106	0.028
Energy drinks consumption [Yes]	–0.184	0.009
Gender [F] * Sleep medications [Yes]	–0.174	0.009
Watch standing [Yes] * Sleep medications [Yes]	–0.202	0.004
BMI * Workout frequency	–0.101	0.026
BMI*Energy drinks consumption [Yes]	–0.114	0.020
Workout frequency * Energy drinks consumption [Yes]	0.118	0.013

DISCUSSION

Results show that this sample of active duty personnel slept approximately six hours per night; considerably less than the 8-hour level recommended by sleep experts. This amount is comparable to previous findings from crewmembers aboard other U.S. Navy ships (Miller et al., 2012; Shattuck & Matsangas, 2014; Shattuck, Matsangas, & Powley, 2015). Given the level of sleep deprivation, it was no surprise that approximately 90% of all respondents reported using at least one type of caffeinated beverage. Coffee was used by approximately 55% of respondents, followed by soft drinks (~ 50%), energy drinks (~ 35%) and tea (~ 35%). Based on their daily consumption, approximately 10% of caffeine drinkers were classified in the Moderate and High caffeine intake groups. Notably, the maximum reported consumption by one participant was 90 cups of coffee, whereas another reported drinking 30 energy drinks per week.

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 that study showed that service members who drank three or more energy drinks per day were more likely to report averaging four hours of sleep or less per night (38.2%) than service members who drank one to two (18.4%) or zero (23.9%) energy drinks per day.

Overall, our study highlights the widespread use of caffeine among active duty crewmembers in our sample. Given that chronic sleep restriction is a common problem while working at sea, caffeine may be an effective fatigue countermeasure. However, our results also suggest that caffeine intake, in the form of coffee, tea, caffeinated soft drinks, or energy drinks, may interfere with sleep patterns. Future efforts should be directed at exploring causal relationships involved in this phenomenon. Better understanding of causal links will enable appropriate guidance for better sleep hygiene in the maritime operational environment.

Study limitations

This study has a number of limitations. The sample size represented 30% of the crew of a single aircraft carrier. The consumption of caffeinated beverages and all other metrics were self-reported. Although height and weight were objectively measured, the use of BMI to assess obesity is also a matter of concern. Future investigations should assess adiposity with metrics other than BMI (Alasagheirin, Clark, Ramsey, & Grueskin, 2011). Lastly, this was not a designed experiment but rather, was observational in nature. Therfore, associations cannot be interpreted as causal.

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