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SAFEGUARDING SLEEP: ASSESSING QUALITY OF LIFE FOR U.S. NAVY SENIOR LEADERS IN THE SURFACE FLEET

by

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March 2023

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SAFEGUARDING SLEEP: ASSESSING QUALITY OF LIFE FOR U.S. NAVY SENIOR LEADERS IN THE SURFACE FLEET

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ABSTRACT

Senior leaders onboard U.S. Navy vessels afloat have constantly evolving schedules that are rarely consistent from day to day. Over the past two decades, studies of work and rest patterns have confirmed anecdotal reports of insufficient sleep of enlisted Sailors. The sleep of senior Officers has not been closely examined. Assessing sleep of surface fleet Officers as they perform their duties in the fleet may provide insight into the bigger picture of health and wellness in the U.S. Navy. As part of a multi-year project, sleep patterns of senior leaders were assessed while in training and in the fleet. An 18-month longitudinal data collection commenced when participants were attending Surface Warfare Schools Command (SWSC) in Newport, RI, and continued as participants assumed their operational positions in the fleet. This thesis takes an initial look into the sleep, mood, and other physiological patterns of senior leaders in these two settings over the first few months of the study. Participants completed validated questionnaires to assess their overall wellbeing and wore physiological monitors (ŌURA rings) to assess the duration and quality of their sleep. In this first opportunity to examine patterns in the data, we found statistically significant differences in sleep duration of senior leaders depending on where they were living and working; that is, when they were attending school, between school and operational command, and after they arrived at their operational command.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

3M	Maintenance and Material Management System
CLAs	Constraints, Limitations, Assumptions
CNO	Chief of Naval Operations
CO	Commanding Officer
CRSD	Circadian Rhythm Sleep Disorders
DOD	Department of Defense
DON	Department of the Navy
FLTMPS	Fleet Training Management and Planning System
GAD-7	General Anxiety Disorder-7
GAO	Government Accountability Office
HRV	Heart Rate Variability
IQR	Interquartile Range
IRB	Institutional Review Board
I-stop	Intermediate stop
MD	Median
N1	Stage 1 (Sleep Stage)
N2	Stage 2 (Sleep Stage)
N3	Stage 3 (Sleep Stage)
NREM	Non-rapid Eye Movement
NTSB	National Transportation Safety Board
NPS	Naval Postgraduate School
OPNAV	Office of the Chief of Naval Operations
PHQ-8	Patient Health Questionnaire-8
PII	Personally Identifiable Information
POMS	Profile of Mood States
PPG	Photoplethysmography
PSQI	Pittsburgh Sleep Quality Index
PSS-10	Perceived Stress Scale-10
PXO	Prospective Executive Officer
REM	Rapid Eye Movement

RFIs	Requests for Information
SD	Standard Deviation
SE	Sleep Efficiency
SecDef	Secretary of Defense
SORM	Standard Organization and Regulations Manual
SWO	Surface Warfare Officer
SWSC	Surface Warfare Schools Command
TIB	Time in Bed
TST	Total Sleep Time
W	Wake/Alert (Sleep Stage)
XO	Executive Officer

EXECUTIVE SUMMARY

In support of around-the-clock global operations, the U.S. Navy's surface fleet provides adversary deterrence, information warfare, intelligence, support to U.S. and allied warfighters worldwide, and much more. Personnel onboard U.S. Navy vessels often work long hours surpassing the regular 40-hour civilian workweek. Their work may include daytime, nighttime, and unusual or novel schedules (Shattuck et al., 2014). As a result of such schedules and long work hours, these operators, support personnel, and leaders face challenges while performing activities such as complex decision making (Olsen et al., 2010).

In 2017, two guided-missile destroyers, USS *Fitzgerald* and USS *John S. McCain*, collided with commercial ships, killing 17 Sailors. These collisions, in addition to the grounding of USS *Antietam* and other safety-related incidents that occurred that same year, brought concerns of sleep deprivation, fatigue, poor situational awareness, lack of manning, and lack of training to the forefront. Since the catastrophic year of 2017, the surface community, as well as the entire Naval enterprise, has invested in sleep and shipboard watch schedule research in an attempt to improve crew sleep, performance, and overall well-being of its Sailors.

Surface Warfare Schools Command (SWSC) is the training center for surface Navy leaders such as Surface Warfare Officers (SWOs) and Naval Aviators selected for command at sea. Upon completion of training at SWSC, Officers are deployed to the fleet to serve as leaders and are expected to maintain a high level of performance, even under the pressures of stressful, complex, and challenging operational environments. These senior leaders must work long shifts, often surpassing the full-time work week (40 hours) standard, which may include irregular schedules and/or shift work. These highly demanding circumstances interfere with obtaining quality sleep which can result in fatigue, degraded cognitive function, and erroneous decision making, especially in ambiguous and/or stressful environments.

The core of this thesis is the question of whether the measurements provided by the commercially available ŌURA rings can provide insight into senior Officers' sleep quality, sleep patterns, and overall readiness. The research questions and goals revolve around senior Surface Warfare Officers' sleep patterns and well-being and how they vary according to demographic, behavioral, and occupational characteristics as well as according to their location, divided into three time periods: time at SWSC, the period between SWSC and reporting to their operational command, and the time at the operational command. It is the intent of this research to establish how ŌURA ring data can be used and explored to safeguard the sleep and overall well-being of senior leadership onboard U.S. naval vessels. This thesis investigates the first several months of data from this longitudinal study.

Using pre-study questionnaire responses, 81 study participants' behavioral characteristics, depression levels, stress levels, mood, and general anxiety were analyzed. Preliminary findings in the data included the following, 75 (93%) of the participants reported consuming at least one caffeinated beverage daily; 66 (88%) of them reported drinking coffee. The average number of servings or cups of coffee consumed per day was approximately 2.6 cups. Only 12 (15%) participants reported not having an exercise routine. Of the 69 participants who engage in physical activity, the average number of times per week an individual worked out was 4.5 times. Only 1 (1%) participant was classified as experiencing symptoms of "major depression" where the rest scored "normal." Participants were classified into three categories: low perceived stress (73% of the participants), moderate perceived stress (26%), and high perceived stress (1%). Out of 80 participants, 31 (39%) participants had a total mood disorder score greater than the 50th percentile.

We used various methods to analyze the data. A mixed-effects effects model analysis was used to assess differences in the duration of major sleep episodes among the study periods. Pairwise comparisons, using the Wilcoxon Signed Rank test, showed that the duration of major sleep episodes differed between both the operational and the SWSC periods, and the operational and the between period. Specifically, the results showed that senior leaders had shorter major sleep episodes during the operational period compared to the other two periods. Results also showed that the number of participants who averaged above seven hours per night of sleep decreased nearly 50% in the Operational Period, compared to the other two periods. The average total sleep time for those who already checked onboard to their operational command was much less with only 5 (22%) of the 23 participants receiving seven hours or more of sleep.

To ensure mission accomplishment, senior leaders must be able to perform their job and perform it well (quickly, accurately, etc.). Insufficient sleep and poor fatigue management can lead to deteriorated attention, performance, and poor decision making. Fatigue, safety mishaps, and deteriorated attention are all negative effects which can result in injury to self and others. The safety of the ship and the life of its crew are the senior leader's responsibility. By incorporating more data and using methods presented in this thesis, we aim to encourage future research that will lead to evidence-based policy changes. Schedules for the senior leaders onboard naval vessels should be optimized with a focus on safeguarding sleep. The result can increase ship safety and mission accomplishment as well as improve quality of life for all onboard. Military leaders need adequate sleep and must be educated to be mindful of how best to manage sleep and fatigue levels to increase mission readiness and safety.

References

Olsen, O. K., Pallesen, S., & Jarle, E. (2010). The impact of partial sleep deprivation on moral reasoning in military officers. *Sleep*, *33*(8), 1086–1090. https://doi.org/10.1093/sleep/33.8.1086

Shattuck, N., Matsangas, P., & Waggoner, L. (2014). Assessment of a novel watchstanding schedule on an operational U.S. Navy vessel. *Human Factors and Ergonomics Society Annual Meeting Proceedings*, *58*, 2265–2269. https://doi.org/10.1177/1541931214581472

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I. INTRODUCTION

I am a United States Sailor.

I will support and defend the Constitution of the United States of America
and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me
to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with Honor, Courage and Commitment.

I am committed to excellence and the fair treatment of all.

—The U.S. Navy's Sailor's Creed
(Naval History and Heritage Command, 2018)

A. OVERVIEW AND BACKGROUND

In support of around-the-clock global operations, the U.S. Navy's surface fleet provides adversary deterrence, information warfare, intelligence, support to U.S. and allied warfighters worldwide, and much more. Personnel onboard U.S. Navy vessels often work long hours surpassing the regular 40-hour civilian workweek. Their work may include daytime, nighttime, and unusual or novel schedules (Shattuck et al., 2014). Many Sailors experience rapidly rotating work schedules where frequent shift changes occur due to various watch or training related reasons. Unfortunately, the expectation is often that the service member should be able to quickly adjust without negative impact on performance (King, 2012; Shattuck & Matsangas, 2019). As a result of such schedules and long work hours, operators, support personnel, and leaders encounter performance challenges in activities such as complex decision making (Olsen et al., 2010).

"Navy Collisions That Killed 17 Sailors Were 'Avoidable,' Official Inquiry Says," "Years of Warnings, Then Death and Disaster: How the Navy failed its Sailors," and "US Navy: 2 Deadly Summer Collisions Were 'Avoidable'" are a few of the headlines published by CNN, ProPublica, and *The New York Times*, respectively. These headlines refer to the two guided-missile destroyers, USS *Fitzgerald* and USS *John S. McCain*, that collided with commercial ships in 2017. These collisions, in addition to the grounding of USS *Antietam* and other safety-related incidents that occurred that same year, brought concerns of sleep deprivation, fatigue, poor situational awareness, lack of manning, and lack of training to the forefront. The U.S. Senate Armed Services Committee held hearings to question senior Navy Leadership and examine why the recent spate of incidents at sea was occurring. One of those questioned was Admiral John Richardson, the Chief of Naval Operations (CNO) at the time. He stated that the Navy was looking into empowering the Commanding Officers to "better-manage the workday of the crew within a repeatable, sustainable, and predictable framework" (Senate Hearing, 2017).

The Navy still faces questions stemming from the CNO's statement that leaders need to "better-manage the workday of the crew" (Senate Hearing, 2017). What about the management of the workday for Navy leaders, specifically the surface senior leaders? Is anyone looking out for the Commanding Officers and Executive Officers? The last two lines of the U.S. Navy's Sailor's Creed proclaim that one serves with "honor, courage and commitment" along with commitment to "the fair treatment of all" (Naval History and Heritage Command, 2018). All U.S. Navy Sailors are Sailors first; in addition to serving the team and other Sailors, the fair treatment of all includes the individual self. Good leadership requires adequate sleep, mindful management of fatigue, and cognizance of constantly evolving operational conditions.

The U.S. Government Accountability Office (GAO) reported in May 2017 that the Navy's reduced-crewing initiatives, dating back to the early 2000s, may have led to overworked crews putting in too long hours. The study also revealed "that crew reductions corresponded with increases in maintenance costs that outweighed the savings achieved through reduced personnel costs" (Government Accountability Office [GAO], 2017, p. 10). Consequently, steps were recommended to make certain that the needs of the present and future surface fleets are met by the Navy's crew requirements. A 2021 GAO report cited two additional National Transportation Safety Board (NTSB) reports that found a main factor of the 2017 collisions was fatigue and specifically stated that "the Navy had no fatigue mitigation program to ensure crews received adequate sleep or had mandatory rest periods" (Government Accountability Office [GAO], 2021, p. 3).

Since the U.S. Navy's surface fleet's tragic year of 2017, the surface warfare community has invested in sleep and watch schedule research, attempting to improve crew sleep, performance, and overall well-being. In 2021, "the surface Navy issued a fatigue management policy that directed the use of circadian rhythm watchbills across the surface fleet" (GAO, 2021, p. 3). This Navy policy (Commander, Naval Surface Force, U.S. Pacific Fleet and Commander, Naval Surface Force Atlantic Instruction 3120.2, Comprehensive Fatigue and Endurance Management Policy [November 30, 2017] and superseded by Commander, Naval Surface Force, U.S. Pacific Fleet and Commander, Naval Surface Force Atlantic Instruction 3120.2A, Comprehensive Crew Endurance Management Policy [December 11, 2020]) states that seven or more hours of sleep is needed for Sailors to safely conduct operations, while acknowledging that it is challenging to get this amount of sleep due to ongoing conditions and high operating demands (Department of the Navy [DON], 2020; GAO, 2021).

Further discussion of the new policy in the most recent GAO Navy Readiness (2021) publication describes how Sailors accumulate sleep debt, also known as sleep deficit, if adequate sleep is not received over time. The Secretary of Defense (SecDef) completed a study in 2021 on service members and the impacts of sleep deprivation (GAO, 2021). The report explained that a service member's effectiveness can significantly degrade due to insufficient sleep. According to the report, insufficient sleep causes a "reduced ability to execute complex cognitive tasks, communicate effectively, quickly make appropriate decisions, maintain vigilance, and sustain a level of alertness required to carry out assigned duties" (Under Secretary of Defense, 2021; GAO, 2021).

Since policy changes may not be enough to solve crew fatigue, a specialized Crew Endurance Team (CET) at the Naval Postgraduate School (NPS), led by Dr. Nita L. Shattuck was called upon by Surface Warfare Schools Command (SWSC). The mission of the CET is to improve crew endurance and overall quality of life onboard U.S. Naval vessels. Shattuck and the CET have conducted sleep and performance studies on over 40 surface ships and several shore-based facilities to document the work and rest patterns of Sailors and implement beneficial changes (Shattuck et al., 2018).

Despite this topic receiving the attention of Naval leadership following the events of 2017, the problems of fatigue and sleep related issues are far from resolved. A 2020 survey conducted by the GAO found that "14 percent of Officers received the recommended 7 hours or more of sleep a day during their most recent deployment, while 67 percent received 5 hours or less" and "Navy data show [s] that Sailor effectiveness declines after prolonged periods without sleep, equating to impairment levels comparable to intoxication" (GAO, 2021, p. 2). The report also concluded that although the Navy updated its policy in December 2020 and is taking steps towards implementation, there are limits imposed by a "lack of quality information on Sailor fatigue and the factors that cause lack of sleep" (GAO, 2021, p. 2). The process of gathering this data and identifying significant factors is important for the Navy to better manage fatigue is the focus of this research.

B. THESIS SCOPE

This thesis studies the sleep and wake patterns of senior leadership of Navy warships with motivation to inform the U.S. Navy about the potential impacts of fatigue, sleep deprivation, and the conditions under which surface warfare leaders are operating. In the Standard Organization and Regulations Manual (SORM) of naval vessels, the charge of the CO is simply and eloquently stated. It says that COs are "charged with the absolute responsibility for the safety, well-being, and efficiency of the ship and crew" (Office of the Chief of Naval Operations [CNO], 2017, 3–1). In contrast, the XO has a detailed list of functions, roles, and responsibilities. According to the SORM, XOs are "the direct representative of the CO and shall be primarily responsible to the CO for the organization, performance of duty, training, maintenance, and good order and discipline of the entire command" (CNO, 2017, 3–2). Additional XO duties and responsibilities often include inspections, supervision and coordination of "work, exercises, training and education of the personnel," drafting operational plans and schedules, issuing daily schedules, ensuring "security measures and safety precautions are observed," evaluating the "performance of Officers and enlisted and personnel," providing recommendations to the CO, regulating liberty and leave, overseeing boards and committees, etc. (CNO, 2017, 3–3). Given the number of roles and critical responsibilities held by senior leaders, it is vital they perform optimally.

Surface Warfare Schools Command (SWSC) is the training center for surface Navy leaders such as Surface Warfare Officers (SWOs) and Naval Aviators selected for command at sea. Upon completion of training at SWSC, these leaders are deployed to the fleet. Such senior leaders are expected to maintain a high level of performance, even under the pressures of stressful, complex, and challenging operational environments. These senior leaders commonly work long shifts, often surpassing the full-time work week (40 hours), which may include irregular schedules and/or shift work. These highly demanding routines interfere with obtaining quality sleep and rest which result in fatigue, degraded cognitive function, and erroneous decision making, especially in ambiguous and/or stressful environments.

In 2017, CET was asked by SWSC to support their Stress Inoculation Training program as one part of their mission to provide the modern warfighter with the tools needed to be effective. Over the past few years, the CET has delivered sleep education and crew endurance training to each Prospective Executive Officer (PXO) class at SWSC, enabling the CET to assess the well-being of SWSC students as they complete their training. Delivered several times a year since 2018, these efforts proved to be highly successful with respect to sleep training and providing crew endurance materials. Post-training assessments, conducted by the CET, showed that PXOs viewed the course favorably and considered the content to be an asset to their preparation for operational assignment.

In addition to the SWSC training program, the CET conducted a PXO Stress Inoculation study which involved measurement of sleep, well-being, and stress load before and after the stress inoculation training at SWSC. The CET established the value of assessing sleep longitudinally using a wearable device called an ŌURA ring. At the completion of the stress inoculation study, multiple participants requested that they be allowed to continue wearing the ŌURA rings as they returned into the fleet to assess their sleep while deployed. This thesis analyzes data collected primarily from PXOs while going through training at SWSC and compares it to data from the same individuals after they report to their next assignment. If patterns are identified and corrections implemented, such as learning where more sleep and less stress could be applied, a better rested senior leader would benefit the entire crew.

The overarching aim of this study is to assess sleep patterns of Navy senior leaders while in training at SWSC, during the time in between SWSC and reporting to the fleet, and after they report to their operational command. Using the data collected thus far, this thesis aims to inform U.S. Navy leadership how to improve sleep patterns and work schedules of senior leaders on naval vessels.

C. STUDY OBJECTIVES

The objectives of this thesis:

- Identify individual factors (e.g., age, sex), occupational factors (e.g., deployment duration, rank), and behavioral factors (e.g., caffeine intake, tobacco use) which are related to the sleep and well-being of senior leaders.
- Assess the sleep/wake patterns and well-being (e.g., mood and daytime sleepiness) of senior leaders during three periods: at SWSC, between SWSC and prior to checking into the operational command, and after checking into the operational command while performing regular duties.
- Compare the sleep and well-being of senior leaders during these three time periods.
- Provide recommendations for future analysts to optimize readiness of senior leaders in the surface fleet.

The primary tool used to collect data for this research is the commercially available ŌURA ring. We aim to explore how best to use these wearable devices to provide insight into the sleep quality, sleep patterns, and overall readiness of senior leaders. To do so, we strive to address the following questions:

- Do the sleep patterns and well-being of the surface fleet senior Officers enrolled in the study differ according to demographic, behavioral, and occupational characteristics?
- Do the sleep patterns and well-being vary according to location (i.e., at SWSC, between SWSC and prior to checking into the operational command, and after checking into the operational command)?
- How can this dataset be used and further explored to safeguard the sleep and overall well-being of leadership onboard U.S. naval vessels?

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II. LITERATURE REVIEW

This chapter summarizes the basics of sleep to include a discussion about the human circadian rhythm and homeostatic sleep pressure. Sleep deprivation within the U.S. Navy and onboard ships, as well as associated effects and consequences on performance and health, are also addressed. This literature review describes various problems associated with sleep and the challenges posed by irregular work and rest schedules, circadian phase-shifting, and mitigations to reduce negative impacts of shiftwork on sleep, health, decision-making, and performance.

A. SLEEP FUNDAMENTALS

Today, many humans chronically fail to get enough quality sleep due to work schedules which are influenced by the demands of contemporary life (Dement & Vaughan, 1999). Miller et al. (2011) states that on average, Americans sleep over two hours less a night than one hundred years ago. The message is that people simply do not sleep enough, and components of modern society may be to blame (e.g., light at night, social pressures, shiftwork, etc.). This section focuses on some fundamentals of sleep and introduces two important concepts: circadian rhythms and homeostatic sleep pressure.

1. Sleep Regulation

Sleep is vital for human performance and well-being. Carskadon and Dement (2011) found that sleep is a "reversible behavioral state of perceptual disengagement from and unresponsiveness to the environment" and that sleep is an intricate combination of physiologic and behavioral processes (p. 16). There are several theories that attempt to explain why we sleep but it is evident, when sleeping, the body grows, heals, and recovers (Zaki et al., 2020).

Two physiological processes affect our tendency to sleep, circadian rhythm and the homeostatic sleep pressure (Borbély, 1982). These two processes regulate the quantity, quality, and timing of sleep (Zaki et al., 2020). According to Shattuck et al. (2019), humans are inherently diurnal, meaning they are naturally active and conscious in the daytime and sleep at nighttime. As a result, the need for sleep and the drive for sleep increases with cumulative wakefulness (Shattuck et al., 2019). In other words, the tendency to sleep increases with the amount of time spent awake. Conversely, the longer one stays awake and the more tired and fatigued a person becomes, the less likely optimal performance is achievable.

The concern about effects of fatigue on senior leaders stems from a schedule in flux when out to sea, causing sleep regulation to become a challenge and potential problem for safe operations. COs and XOs onboard vessels afloat may have events penciled in on their daily schedule, but often do not follow a hard-and-fast, written schedule or watch rotation. This reality often results in other tasks getting prioritized over restful sleep, causing senior leaders to not get adequate time for sleep. Miller et al. (2011) stated that military forces are faced with "chronic sleep deprivation, resulting in sleep debt that affects performance and safety" (p. 53).

2. Circadian Rhythms

According to Xie et al. (2019), a person's circadian rhythm is a "series of endogenous oscillators generated by the molecular circadian clock, which acts on coordinating internal time with the external environment in a 24-hour daily cycle" (p. 1). Additionally, circadian rhythm is not permanently fixed and can be influenced by one's daily lifestyle and behavior. The circadian clock is "an internal regulator in cells of organisms," and its operation "coordinates physiological and behavioral activities with daily environmental variations within 24-hour cycles" (Farhud & Aryan, 2018, p. 1068). Such "activities" (bodily processes) include sleep-wake cycles, hormonal activity, body temperature rhythm, and eating and digesting. In fact, Circadian Rhythm Sleep Disorders (CRSD) result from a recurring pattern of sleep-wake disruption brought on by circadian clock dysfunction or misalignment, which can lead to impairments and various sleep disorders (Zhu & Zee, 2012; Patke et al., 2017). According to Sateia (2014), "Recent evidence clearly shows that circadian dysfunction not only impairs sleep and wake performance but also negatively affects the function of multiple organ systems, and increases the risk for cardiovascular, metabolic, cognitive, and mood disorders" (p. 11).

These disorders can have more severe consequences on human health such as reduced resilience and recuperative ability (Xie et al., 2019).

Working or being awake from midnight to dawn almost always disturbs one's circadian rhythm (Miller, 2008). Miller concluded that circadian rhythms might shift up to 45 minutes for each night without sleep (experienced by a person who would normally be sleeping in a diurnal rhythm). Such shifts may lead to detrimental effects similarly felt from jet lag, also known as shift lag. Often experienced when traveling across several time zones, jet or shift lag occurs when an individual's circadian rhythm is mismatched from the diurnal cycle of their current location. Additionally, Miller (2008) suggested that the effects (such as fatigue) may be greater after the second night without sleep compared to the first night -- and will likely worsen with each subsequent night of sleep loss. Circadian rhythm disruption has become a major concern in contemporary society and studies on individuals who experience jet lag or inconsistent schedules demonstrated that it "can cause cognitive impairment, psychiatric illness, metabolic syndrome, dysplasia, and cancer" (Xie et al., 2019).

In today's world, humans more commonly work and sleep at times conflicting with their natural circadian rhythm and daylight hours. This includes senior military leaders where inconsistent work schedules can disrupt the synchronization between the 24-hour day and the circadian rhythm. By understanding circadian biology and circadian rhythms and adapting planned work schedules with these facts in mind, quality of life and performance would be beneficially influenced both at home and in the workplace (Farhud & Aryan, 2018).

3. Homeostatic Sleep Pressure

The homeostatic process, one of the two interactive processes which modulate sleep-wake patterns and alertness levels (circadian rhythm being the other process), is the drive for sleep that increases when we stay awake and decreases during periods of sleep (Borbély, 1982; Fang & Rao, 2017). In other words, the pressure for sleep builds as the time we are awake increases. Said another way, the longer we stay awake, the stronger the pressure to sleep becomes. With sleep, the pressure decreases and goes away completely after obtaining a full night of quality sleep. Sleep debt is the result when a person does not get enough sleep and the remaining sleep pressure carries over into the next day. Once awake, the process starts over, and the homeostatic sleep pressure will begin to build again. If adequate sleep is not obtained, a person's sleep debt can build and build, further worsening its affects. Dawson and Reid (1997) conducted an earlier study similar to a study done by Williamson and Feyer (2000), which showed that the build-up of sleep debt resulted in similar performance to drunk drivers with blood alcohol concentrations (BAC) exceeding the legal limit. They stated, "After longer periods without sleep, performance reached levels equivalent to the maximum alcohol dose given to subjects (BAC of 0.1%)" (Williamson and Feyer, 2000, p. 649).

It is important for humans to obtain consistent sleep to combat the accumulation of homeostatic sleep pressure. Regular and consistent sleep entails going to sleep at or around the same time each day to support the alignment of an individual's sleep-wake schedule with their circadian rhythm. According to Fang and Rao (2017), "negative effects of homeostatic sleep debt on brain function have been demonstrated by studies using neuroimaging techniques" (p. 495). Such studies reveal that sleep loss "impairs brain activations during various cognitive tasks" and modifies "functional connectivity at resting state without task demands" (p. 495). An additional study revealed that "activation in the fronto-parietal attention and salience networks were significantly decreased, and activation in the thalamus increased after acute total sleep loss" (Ma et al., 2015, p. 233).

4. Sleep Stages

Sleep is typically divided into five stages: wake/alert (W), stage 1 (N1), stage 2 (N2), stage 3 (N3), and rapid eye movement (REM) (Patel et al., 2022). Non-rapid eye movement (NREM) sleep includes stages N1 through N3, with each stage corresponding to a deeper state of sleep. During the course of four to five sleep cycles in a typical night, the sequence of the sleep stages often occurs in the order N1, N2, N3, N2, REM where a single sleep cycle takes between 90 and 110 minutes (Feinberg & Floyd, 1979).

To better understand sleep stages, Patel et al. (2022) divides the stages up by the approximate percentages of time the normal human spends in each stage. During stage W, the individual is awake regardless of having opened or closed eyes. Depending on if the eyes are opened or closed, the individual will either remain in the current stage or shift into the next stage. N1 is the lightest stage of sleep, accounting for 5% of total sleep time. The individual's breathing is considered normal during this stage. The next deeper sleep stage, N2, occurs when the heart rate and temperature of the body drops, accounting overall for 45% of the total time sleep. Initially, a normal adult will be in N2 for about 25 minutes in the first cycle, but this time lengthens during follow-on cycles. In the deepest stage of NREM sleep, N3, it is most difficult to wake up and accounts for 25% of time asleep. The last sleep stage is REM, when it is most common to dream. The length of REM stage varies, but typically extends in length over the course of a night's sleep. REM commonly starts after the first 90-minutes and lasts about 10 minutes with the last REM stage taking up to 60 minutes to complete (Della Monica et al., 2018). According to Patel et al. (2022), REM accounts for much of the final 25% of total sleep time.

B. EFFECTS OF SLEEP DEPRIVATION

Documentation regarding the study of the effects of sleep loss on performance in the military date back as early as 1990 (Naitoh et al., 1990). Since then, more studies on sleep deprivation in civilian and military populations were conducted resulting in significant knowledge gained. Harrison and Horne (2000) found that sleep deprivation impairs decision making which may cause ineffective communications, competing distractions, and a need for formulated plans to be revised.

Diekelmann and Born (2010) characterized sleep deprivation and its effect on "various cognitive domains including attention, working memory, abstraction, and decision making," explaining that sleep deprivation "results in decreases in both the encoding of new information and memory consolidation" (pp. 121–122). In terms of combat or operational performance, Belenky (2006) concluded that "sleep deprivation degrades the higher, more complex mental processes" (p. 2), which can result in a loss of battlefield awareness. Their research indicates that the result of this degradation was the individual's "ability to integrate information into a coherent and accurate representation of the tactical situation" became ineffective (p. 2). Although the simplest mental processes may be unaffected, such as Belenky's (2006) example of placing crosshairs on a target and firing rounds accurately down range, a sleep-deprived individual's orientation to the terrain and tactical situation at hand may be degraded with sleep loss.

Sleep deprivation can result in a number of negative effects ranging from acute to more chronic issues. This section explores general problems that tend to occur and are associated with acute or chronic sleep deprivation.

1. Effects of Acute Sleep Debt

The effects of sleep deprivation can vary from minor effects such as fatigue to major effects such as bodily shutdown or even death. Sleep-deprived individuals may unintentionally fall asleep which may lead to accidents in the workplace. Shattuck et al. (2019) explains, "work periods of greater than 8 hours carry an increased risk of accidents," and that "risk is cumulative: the risk of accidents at 12 hours on-duty is twice the risk at 8 hours on-duty" (p. 8). Accidents can vary in severity and may include physical injury as well as psychological injury. Although sleep recovery can occur if time allows, constantly changing the timing of one's sleep and the number of hours of sleep obtained is not conducive to fighting fatigue and preventing mishaps (Naitoh et al., 1990).

Some familiar effects of sleep deprivation include fatigue, burning eyes, inability to focus, and irritability. Lack of sleep is known to cause a "general slowing of response speed and increased variability in performance, particularly for simple measures of alertness, attention, and vigilance" (Killgore, 2010, p. 105). Shattuck et al. (2019) separates effects of poor sleep into short-term (focused more on performance decrements), intermediate, and long-term effects (focused more on chronic health effects). Short-term and intermediate effects listed by Shattuck et al. (2019) include slower reaction times, decreased vigilance, inconsistent logical reasoning, reduced short-term memory, negative mood, increased stress hormone production, loss of motivation and morale, poor memory, decreased immunity, increased caffeine intake or addiction, etc. Long-term effects will be discussed in a later section.

a. *The Effect of Sleep on Well-being*

An individual's well-being is affected by the amount and duration of sleep deprivation experienced. In laboratory conditions, sleep loss has been characterized into three categories: total sleep deprivation (the individual is kept awake), partial sleep deprivation (the major sleep episode is shortened), and selective sleep deprivation (individuals are awakened when they enter a certain sleep stage, for example REM). The accrual of sleep debt can also be considered as two distinct types: acute sleep deprivation (a single night of sleep loss) and chronic sleep deprivation (inadequate sleep over multiple nights). Mood deteriorates and motivation to work is lowered during total or partial sleep deprivation. Individual well-being and psychological state are influenced by sleep loss and may include mood changes, irritability, petulance, tiredness, and stress. Sleep deprivation may result in increased confusion, tension, and depression as well as a loss of efficiency and performance (How et al., 1994). Thus, the well-being of a senior leader who is not on a regular schedule may begin to suffer because of a compilation of sleep loss from day to day.

b. *Deteriorated Attention Resulting from Sleep Loss*

As a product of fatigue and sleep deprivation, cognitive functions such as attention are affected. In their review of the effects of sleep, Harrison and Horne (2000) noted that sleep deprivation impairs real-world decision making, "tasks which involve unique and unfamiliar circumstances, necessitating a wide range of other complex skills" (p. 237). Harrison and Horne (2000) list the following examples: assessing risk, anticipating consequences, managing events, developing and maintaining plans, memory of past events, controlling mood, and avoiding distractions. These tasks contain many of the critical items senior leaders perform onboard Navy ships for themselves and their Sailors. Limited or reduced focus and the inability to make decisions due to sleep loss can have dire consequences.

2. Effects of Chronic Sleep Dept

In his classic treatise on the importance of sleep for military leaders, Jonathan Shay discusses how sleep deprivation and fatigue may result in catastrophic operational failure, fratricide, collisions, noncombatant casualties, loss of emotional control, and blind obedience to militarily irrational or illegal orders (Shay, 1998). Negative effects on a person's health, cognitive function and performance, and physical performance become enhanced and even life-threatening as sleep deprivation worsens. Larger-scale or more long-term effects include elevated mishap rates, failure to accomplish the mission, circadian scarring or permanent alteration of circadian rhythm, metabolic disorders, and chronic disease (Shattuck et al., 2019).

a. Effects on Cognitive and Physical Performance

Based on several lab and field studies on sleep deprivation, the risk of significant performance impairment is increased if individuals receive "less than 5 hours sleep in the preceding 24 hours as well as less than 12 hours sleep in the preceding 48 hours" (Costa, 2015, p. 438). Both homeostatic pressure and circadian rhythm "interact in determining the extent of the reduction in alertness and psychophysical performance over the waking day, and even more so at night" (Costa, 2015, p. 439). Effects on cognitive and physical performance can result in risk to mission, poor decision-making leading to accidents, inability to efficiently complete tasks, and lead the Sailors. Moreover, chronic sleep debt diminishes cognitive functions such as creativity, reasoning, innovative thinking, and even strategic planning (Killgore, 2010).

b. Health

When operating on insufficient and inadequate sleep, impacts on general health are likely. Emphasized by Costa (2015), those who do not get enough sleep have an increased probability of illness.

Costa (2015) lists risk factors for health and well-being:

> Deterioration of psychophysical conditions, digestive disturbances, anxiety, irritability, and perturbation of women's hormonal and reproductive functions. In the long term, [chronic lack of sleep] may result in more severe disorders mostly of gastrointestinal, neuropsychologic, or cardiovascular function and, probably, cancer. (p. 437)

After sleep complaints, “digestive troubles are the most frequently reported complaint (20-75%) by shift workers versus day workers (10–25%)” (Costa, 2015, p. 441). Additionally, Costa (2015) cites epidemiologic studies by Ha and Park (2005) and Knutsson and Boggild (2010) which determined that “shift and night work result in a two to five times greater risk for gastrointestinal diseases, such as gastroduodenitis, peptic ulcer, irritable-bowel syndrome, as well as metabolic disorders (dyslipidemic syndrome and type 2 diabetes)” (p. 441).

In this chapter, we summarized the basics of sleep to include a discussion about the human circadian rhythm and homeostatic sleep pressure. Sleep deprivation within the U.S. Navy and onboard ships, as well as associated effects and consequences on performance and health were also addressed. This literature review described various problems associated with sleep and the challenges posed by irregular work and rest schedules, circadian phase-shifting, and homeostatic sleep pressure. We then introduced the negative effects of sleep deprivation on health, performance, and decision-making.

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III. METHODS

A. OVERVIEW

This chapter explains the methodology followed and the steps we took in the thesis. This research required data to be repeatedly collected from the same people over multiple points in time (also called a longitudinal study). The source of our data were volunteers who were attending training at the Surface Warfare Schools Command (SWSC) in Newport, RI. This longitudinal study emerged from another study at SWSC, the Stress Inoculation Training (SIT) study, which originally started in July 2019. In the SIT study, PXOs attending SWSC were first given a briefing on sleep and stress. Stress was then deliberately induced through a week of exercises, an extension of the PXO curriculum. Following an enrollment brief and obtaining consent, volunteers from the PXO class completed a series of questionnaires using the Qualtrics web-based platform. ŌURA rings were then issued to those volunteer participants with the direction to wear the rings continuously for the remainder of the 9-week course.

Some of the PXO volunteers expressed an interest in continuing to wear the ŌURA rings after graduating from the PXO course. As a result, a number of surface warfare Officers and senior leaders continued to wear the ŌURA devices after their graduation from SWSC. Some of these individuals proceeded to various intermediate stops (I-stops) before getting to their next duty station while some of them proceeded directly to their operation command. Thus, the data can be categorized into three different time periods: the timeframe at SWSC while undergoing training, the time between SWSC and the follow-on operational billet, and the time after participants arrive at their respective operational commands. These three periods going forward will be referred to as the SWSC Period, Between Period, and Operational Period. To collect data, we used two primary methods. Questionnaires covered self-reported demographics, sleep estimates, and subjective health estimates while wearable physiological monitors (ŌURA rings) collected objective data on sleep duration, and quality, heart rate, heart rate variability, respiratory rates, and body temperature.

B. PARTICIPANTS

From 2020 to 2022, 147 Navy Officers who were attending the Prospective Executive Officer (PXO) Course in Newport, RI volunteered to participate by answering questionnaires and wearing ŌURA rings. All participants provided informed consent and the study protocol was approved by the Naval Postgraduate School's Institutional Review Board (IRB), NPS.2019.0031-AM06-EP3-4-6-7-A. Demographic information about the participants is shared in Chapter IV.

C. DATA COLLECTION

The methods used to collect data included various standardized questionnaires and wearable, electronic devices called ŌURA rings. These methods reduced the need for in-person engagement with participants. By doing so, study participation is less burdensome, which in turn, resulted in improvements in study participation, data collection rates, quality, and consistency. The questionnaires and ŌURA rings are discussed in the next section.

1. Questionnaires

The informed consent acknowledgement and a one-time series of questionnaires were administered electronically through the Qualtrics web-based platform before data collection from the ŌURA rings began. Therse questionnaires (Appendices A-E) are described in the following sections. The pre-study questionnaire (Appendix A) included items to assess demographic information, health-related behaviors, and military experience. In addition to the demographic section of the questionnaire, participants completed the Patient Health Questionnaire (PHQ-8) (Kroenke et al., 2009), the Perceived Stress Scale (PSS-10) (Cohen et al., 1983), the Profile of Mood States (POMS) (McNair et al., 1971), and the General Anxiety Disorder-7 (GAD-7) (Spitzer et al., 2006). Each participant was assigned a unique participant identification number to maintain anonymity and safeguard personally identifiable information (PII).

a. *Patient Health Questionnaire—8 (PHQ-8)*

The Patient Health Questionnaire (PHQ-8) assesses depression symptoms (Kroenke et al., 2009; Razykov, Razykov et al., 2012). The questionnaire (Appendix B) consists of eight questions that are scored on a scale with values from 0 to 3 (0 – Not at all, 1 – Several days, 2 – More than half the days, and 3 – Nearly every day). After summing the responses, the result is the final score of the PHQ-8 with a maximum possible score of 24 (Kroenke et al., 2009; Razykov et al., 2012). Using their rating scale, Kroenke et al. (2009) deemed "Major Depression" to be present when a score falls between 10 and 20, while "Severe Major Depression" is present when a score exceeds 20. A score of 10 or less indicates a "Normal" result.

b. *Perceived Stress Scale—10 (PSS-10)*

The Perceived Stress Scale (PSS) assesses individual stress levels. The instrument contains 10 questions which ask about the thoughts and feelings an individual has experienced over the past month (Cohen et al., 1983). The PSS-10 (Appendix C) questions are scored on a scale with values ranging from 0 to 4 (0 – Never, 1 – Almost never, 2 – Sometimes, 3 – Fairly often, and 4 – Very often). The total score is summed up with a minimum possible score of 0 and maximum possible score of 40. Individual PSS scores may fall into three categories with the lowest stress scores ranging between 0 and 13. Scores between 14 to 26 fall into the moderate stress category, whereas the highest category of scores (27 to 40) are indicative of high perceived stress.

c. *Profile of Mood States (POMS)*

The Profile of Mood States (POMS) has been used in a variety of applied and research settings to assess mood (McNair et al., 1971). It consists of 65 words or phrases that describe feelings that people may have. The user is asked to choose an appropriate response based on how they felt over the past week. Responses to POMS yield six mood factors: Factor T (Tension-Anxiety; 9 items; range 0–36), Factor D (Depression-Dejection; 15 items; range 0–60), Factor A (Anger-Hostility; 12 items; range 0–48), Factor V (Vigor-Activity; 8 items; range 0–32), Factor F (Fatigue-Inertia; 7 items; range 0–28), and Factor C (Confusion-Bewilderment; 7 items; range 0–28). POMS can be used to calculate a Total

Mood Disturbance (TMD) score by simply adding the scores from each of the six factors, weighting Vigor-Activity negatively. In other words, to calculate TMD, the score for Vigor-Activity, ranging from 0–200, is subtracted from the sum of the other five factors. Based on norms of adults, established by Nyenhuis et al. (1999), an individual is deemed to exhibit a particular quality at that moment if their score is higher than the median score for adults in the general population (50th percentile).

d. Generalized Anxiety Disorder – 7 (GAD-7)

The Generalized Anxiety Disorder (GAD-7) questionnaire (Appendix D) assesses the severity of generalized anxiety symptoms over the previous two weeks (Spitzer et al., 2006). Participants respond to seven scaled and graded items, rating responses from 0 to 3 (0 – Not at all, 1 – Several days, 2 – More than half the days, and 3 – Nearly every day). These seven items involve scaling the following feelings: 1 – nervousness, anxiousness, or edginess, 2 – the ability to stop or control worrying, 3 – the frequency of worrying too much, 4 – trouble relaxing, 5 – experience difficulty sitting still, 6 – irritability, and 7 – feelings something bad may happen. The GAD-7 score is the total of the seven items and ranges from 0 to 21. The score indicates an individual's level of anxiety with scores of 0 to 4 indicating minimal anxiety, 5 to 9 indicating mild anxiety, 10 to 14 indicating moderate anxiety, and 15 to 21 indicating severe anxiety.

2. Sleep Evaluation

To evaluate the sleep of study participants, we used wearable electronic devices known as ŌURA rings (see Figure 1) (Ōura Health Oy, 2020). According to de Zambotti et al. (2019), these devices represent a validated method to collect objective sleep data in field studies. ŌURA rings were used in this study to gain a comprehensive view of the sleep patterns, sleep habits, and overall well-being each participant. In-person engagement was decreased because measurements were recorded through the ŌURA automated application online, which was extremely beneficial due to the COVID-19 restrictions which were in place at the start of the study.

Figure 1. ŌURA ring heritage style
Source: Ōura Health Oy (2023).

ŌURA rings collect multiple metrics including the wearer's movement, heartbeat, and skin temperature; however, this study focused on metrics related to sleep. Table 1 lists sleep-related measurements collected from the rings. Accelerometers, infrared photoplethysmography (PPG), and temperature gauges are used to collect biometric data (Ōura Health Oy, 2023). Based on individualized personal information and algorithms used within the ŌURA application, personalized recommendations are made to modify individuals' habits and routines which affect their sleep measurements.

Table 1. ŌURA ring sleep measurements

Sleep Measurements	Units
Total Sleep Time (TST)	Seconds
Sleep Duration (SD)	Seconds
Sleep Efficiency	Range: 0–100% (100% * TST/SD)
Sleep Score	Range: 1–100, or 0 if not available
Deep Sleep	Seconds
REM Sleep	Seconds
Light Sleep	Seconds
Wake-up Time	Datetime
Ideal Bedtime	Datetime
Bedtime	Datetime
Latency	Seconds

D. RELEVANT VARIABLES

In this section, we operationally define three variables fundamental to this study: workload, sleep efficiency, and readiness. These three complex terms, workload, sleep efficiency, and readiness, are critical to this research, and are interrelated.

1. Workload

The Cambridge Dictionary (n.d.) defines workload as “the amount of work to be done, especially by a particular person or machine in a period of time.” Workload in the context of this thesis denotes predominately mental or cognitive workload on senior leaders. To prevent or combat workload overload, one must identify if an excess of workload exists and where excessive workload is occurring.

In this thesis, we use a self-reported measure, a simple numerical workload measurement. To assess workload, subjects are asked to “rate their overall workload, at periodic intervals, on a scale from 0 to 100” (Casner & Gore, 2010, p. 7). Researchers examined the extent to which subjects’ assessments of their workload are influenced by their opinions on the caliber of their own job. In other words, when subjects feel their performance is subpar, they might also feel they have an above average workload. In addition, physiological measurements of workload that can be used include heart rate, heart rate variability, and evoked potentials (Casner & Gore, 2010). Having this type of data could provide insight into how the individual leader assesses his or her own level of workload, as well as the ability to analyze biometric data collected. Additionally, comparisons can be conducted between timeframes when members claim workload is highest to timeframes when the results of an individual’s vitals/biometric data indicate an abnormality.

2. Sleep Efficiency

Sleep efficiency is the quality of sleep an individual receives in a single night or on average over many nights. Sleep efficiency (SE) is a measure of sleep quality and it is defined as the proportion of total sleep time (TST) to time in bed (TIB) (Reed & Sacco, 2016). Instead of assessing SE with polysomnography (sleep studies used to diagnose sleep disorders), we measure sleep efficiency using wearable devices which calculates SE for us. According to ŌURA ring application descriptions, the ratio of time asleep to time awake when in bed is known as sleep efficiency (Ōura Health Oy, 2020). It considers all sleep, including naps. With respect to ŌURA ring output, a sleep efficiency score of 85% or better is a sign of peaceful and uninterrupted sleep. With increasing age, however, a slight decrease in sleep efficiency can be expected and senior leaders are generally the oldest crew members on a ship. Sleep efficiency can also be influenced by caffeine intake, daily activity, prescription or non-prescription medications, and the levels of stress an individual is currently undergoing.

3. Readiness

The Cambridge Dictionary (n.d.) defines readiness as "the state of being ready or prepared." Readiness is relevant to this thesis because it can provide insight into whether individuals are ready to perform the day's activities. Readiness is influenced by workload and sleep efficiency.

In this thesis, we use the ŌURA rings to measure readiness. The measurement of readiness typically includes recent activity, sleep patterns, and physiological signals which can signify if an individual is under stress. Readiness scores range from 0 to 100 and are an indication of how someone should channel their daily energy. Specifically, a score of 85 or higher indicates that an individual is in an optimal state of readiness, 70–84 is a rating of good with a caveat that an individual may not have recovered well enough. A score of under 70 indicates that an individual needs to pay attention because he or she has not fully recovered from the prior day's activities (Ōura Health Oy, 2020). The readiness score, unique to the ŌURA ring, focuses on trend analysis and health status, which changes over time. Besides readiness scores and contributors, four additional readiness metrics are used in the calculation of the ŌURA readiness assessment. These metrics include average resting heart rate, heart rate variability, change in body temperature, and respiratory rate (Ōura Health Oy, 2020). With knowledge of overall assessed readiness, determinations can be made as to how to mitigate fatigue and encourage positive or enhanced readiness.

E. ANALYTICAL APPROACH

1. Data Cleaning and Data Reduction Procedures

The data cleaning and reduction procedures for this thesis were extensive but critical for deciding which participants could be used in the study. Sixty-two of the 147 participants (42%) confirmed by e-mail their most recent and current locations. Having this information provided knowledge of precise dates, I-stops, and locations which was necessary to categorize the data. Post data collection analysis was performed at the Naval Postgraduate School in Monterey, CA. The original rosters needed to be cleaned and consolidated to establish whose data was usable. Once the information was gathered, cleaned, interpreted, and analyzed, the participants' location data could be consolidated effectively. The questionnaires and wearable data could then be cleaned and consolidated prior to final analysis.

a. Roster(s)

The SWSC class rosters consisted of a mixture of participant IDs, e-mail addresses, and duplicates of point of contact information. To address these issues, a separate file was created with a comprehensive consolidation of all possible members by use of email addresses. E-mail addresses were the only consistent information that existed across all parts of the study, i.e., study rosters, raw questionnaire data, and ŌURA data. The 361 e-mail addresses turned into only 147 once all duplicate e-mail addresses were removed.

With this cleaned list, a new Excel workbook was created and formatted to support the data requiring confirmation from participants. The majority of the participants lacked operational assignment dates and SWSC class dates, which are both required in order to conduct comparative analysis of the milestones. As a result, all 147 senior Officers participating in this effort were e-mailed requesting the following information: Ship/duty station name, start date, SWSC start and end dates, the participant's current and/or prospective operational position, when his or her operational tour was expected to end, and any additional information that could be provided. An example and template were provided to make this easy and less time consuming for them.

Each of these pieces of requested information became a separate column in the table. One additional column was added to track participants who had more than one participant ID; another column was added to track whether a participant responded via email and/or if the participant was located in the Fleet Training Management and Planning System (FLTMPS). FLTMPS is a Navy system that provides a service member's career data to include current billet location, where the participant is headed for their operational tour if not yet onboard, and the arrival date or prospective arrival date. Looking up each person by name (Assuming a name is known and spelled correctly!), is essential to this thesis but also serves to support the research team as well as the next student who may take on the continuation of this thesis.

b. Participant Clarification and Consolidation

The initial data set included data from 147 participants. Of these 147, 62 out of 147 participants (42%) of the members replied to the e-mail with the information requested. All others (the remaining 58%) were located in FLTMPS. There is some overlap with the 62 email respondents because email responses continue to be received and information is constantly being updated.

Participants used in this study could officially be determined with the completed master roster table and matched up with those who completed questionnaires and/or for whom ŌURA data has been collected. The roster aided in the cleaning of the questionnaires because there were missing IDs, and some had no names associated with the data. Similarly, the ŌURA data only contained IDs and no name associations.

For the remainder of this section, the consolidation and decisions made about participant inclusion will be briefly discussed. In general, participants with missing and incomplete data were removed before the analysis was conducted. The results reported represent only those participants who supplied all necessary data.

To formulate a collective view of the participants who completed the questionnaires in full, as well as those whose wearable data has been collected, five individual tables were created and aligned side-by-side. After the columns were organized and highlighted, the final study sample used for analysis included 92 participants. This sample includes the 62 participants who had both questionnaire and ŌURA data, 12 participants with only ŌURA data, 18 participants who provided questionnaire responses, and a single member with ŌURA data collected and completion of two of the four questionnaires. Figure 2 is the consort flow diagram illustrating the breakout of participants used for analysis in the longitudinal study analysis.

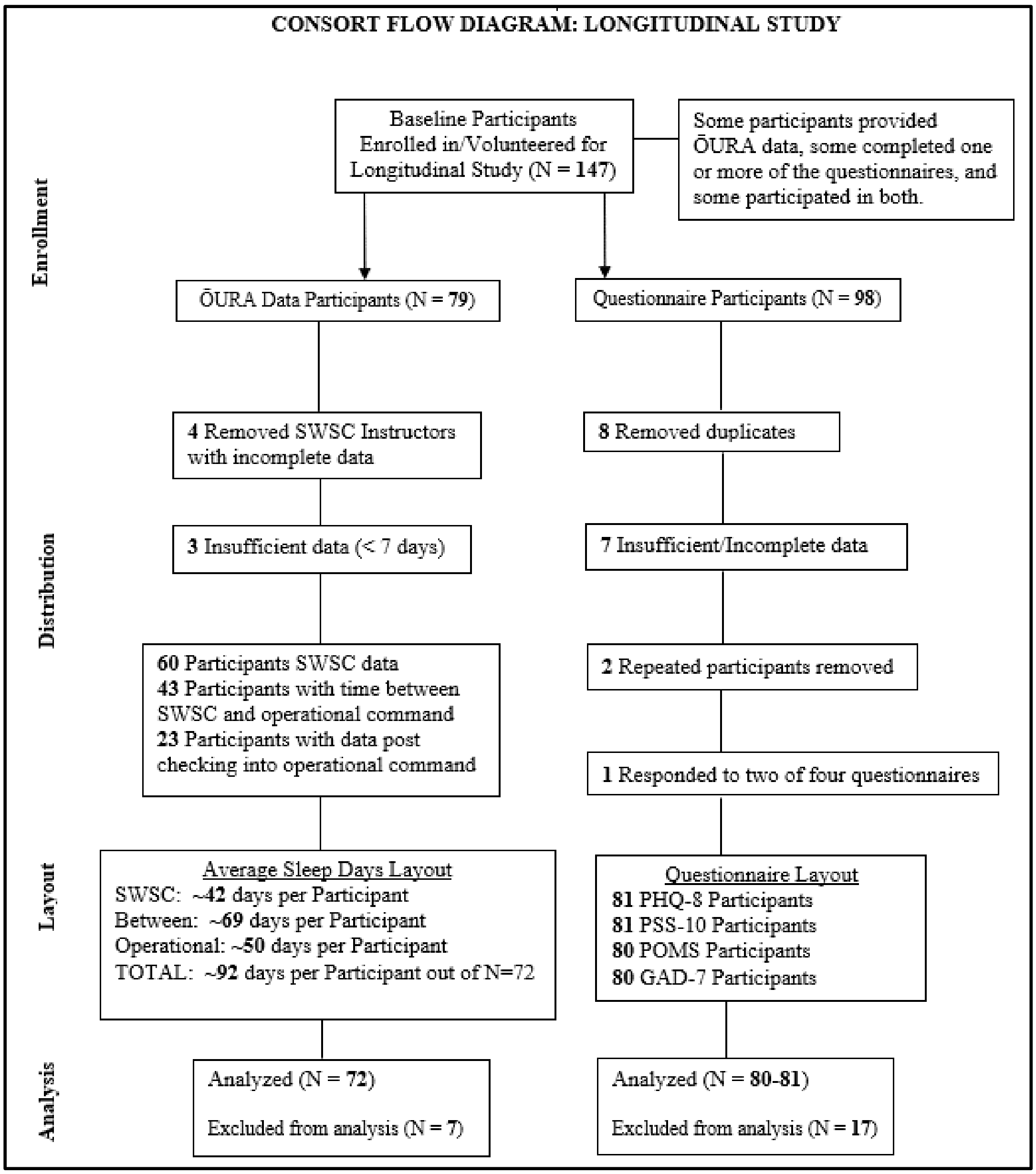


Figure 2. Consort flow diagram for the longitudinal study

c. *Questionnaire Cleaning and Scoring*

The first step to cleaning the questionnaire data was to locate and fill in the missing participant IDs. One participant with a misspelled name had to be contacted to verify her participant ID. The next step was to remove rows with missing or incomplete data. A total of 17 rows were removed.

Excel functions were used for each questionnaire to change categorical data to numerical values for the purposes of scoring and analysis. Following the transition from categorical data to numerical values, templates containing standardized formulae were used to conduct the scoring part for each questionnaire.

d. *ŌURA Data Cleaning and Compilation*

Cleaning ŌURA data was done by compiling 18 sleep-related Excel workbooks of data together. Once compiled, the new workbook contained over 6,000 rows of data for 75 participants. Each Excel workbook consisted of a different date range. The last change was to change the time units from seconds to hours for the columns that would be used for analysis. Time units were changed to hours in this analysis for sleep duration and total sleep time.

2. Analysis Roadmap

The final datafile for analysis included 92 participants of which 62 had both questionnaire and ŌURA data, 12 participants with only ŌURA data, 18 participants who provided questionnaire responses, and one participant with ŌURA data collected and who completed only two of the four questionnaires.

Initially, descriptive statistics were used to describe participants' demographic characteristics. The demographics and the participants' status at the start of the primary data collection period were determined using descriptive analysis of the study sample. Sleep-related metrics were compiled by participant and study periods. The online ŌURA Teams data collection platform was used to acquire participant data, and sleep data was collected with the ŌURA devices. Senior leaders reported anywhere from 13 to 188 distinct sleep episodes. Each participant's average score was calculated based on the aggregation of their daily sleep duration. Daily sleep duration therefore offered an overall indication of an individual participant's level of sleep debt. All data underwent descriptive statistical analysis to identify anomalous entries.

JMP statistical software was used for the inferential statistical analysis (JMP Pro 16; SAS Institute; Cary, NC). The Shapiro-Wilk test was used to determine whether the data were normally distributed. Statistical significance was determined at an alpha level of 0.05. For continuous and categorical variables as number or percentage (#,%), summary data are presented as mean ± standard deviation (M ± SD) or median (MD) (interquartile range – IQR) as necessary. The comparison of POMS scores with adult norms was performed using the precise 1-sided binomial test. Relationships within and between sleep, anxiety, depression, and stress were examined using analysis of variance. Pairwise correlation analysis was conducted on age and questionnaire scores. Dependent variables were analyzed using comparisons with sexes and rank groups to identify the most influential variables during training.

IV. RESULTS

A. PARTICIPANTS

There were 147 individuals who volunteered for the study. Due to attrition and lack of consistent study involvement, the final study analysis sample (n=92) includes the following: 62 participants completed all questionnaires and contributed ŌURA data, one participant who completed two of the four questionnaires and supplied ŌURA data, 12 participants with only ŌURA data, and 18 participants who provided only questionnaire responses. Figure 2, the consort flow diagram for the longitudinal study shown in the previous chapter, lists detailed information which was used to select participants. Analysis of descriptive data included demographic and occupational characteristics, and self-reported health-related behaviors of the 81 participants who completed the initial questionnaire. This data was collected one time approximately half-way through the PXO course while in training at SWSC.

B. DEMOGRAPHIC CHARACTERISTICS (N=81)

The study sample included 5 (6%) females, 75 (93%) males with one individual declining to respond. The average age of the study sample was 39 years (SD=3.66). The median age of the female participants was 38 years (IQR = 6; range from 29 to 39 years). The median age of the male participants was 38 years (IQR = 4; range from 32 to 46 years). Table 2 shows the demographics of the study participants. Figure 3 depicts the distribution of ages compared to sex of the females and males.

Table 2. Participant demographics

Demographics	
Gender, # (%)	
Females	5 (6%)
Males	75 (93%)
Age in Years M ± SD	39 ± 3.66
Ages by Gender	
Female Age Range, # – #, Mean ± SD	29-39, 36 ± 4.06 yrs
Male Age Range, # – #, Mean ± SD	32-46, 38.87 ± 3.61 yrs

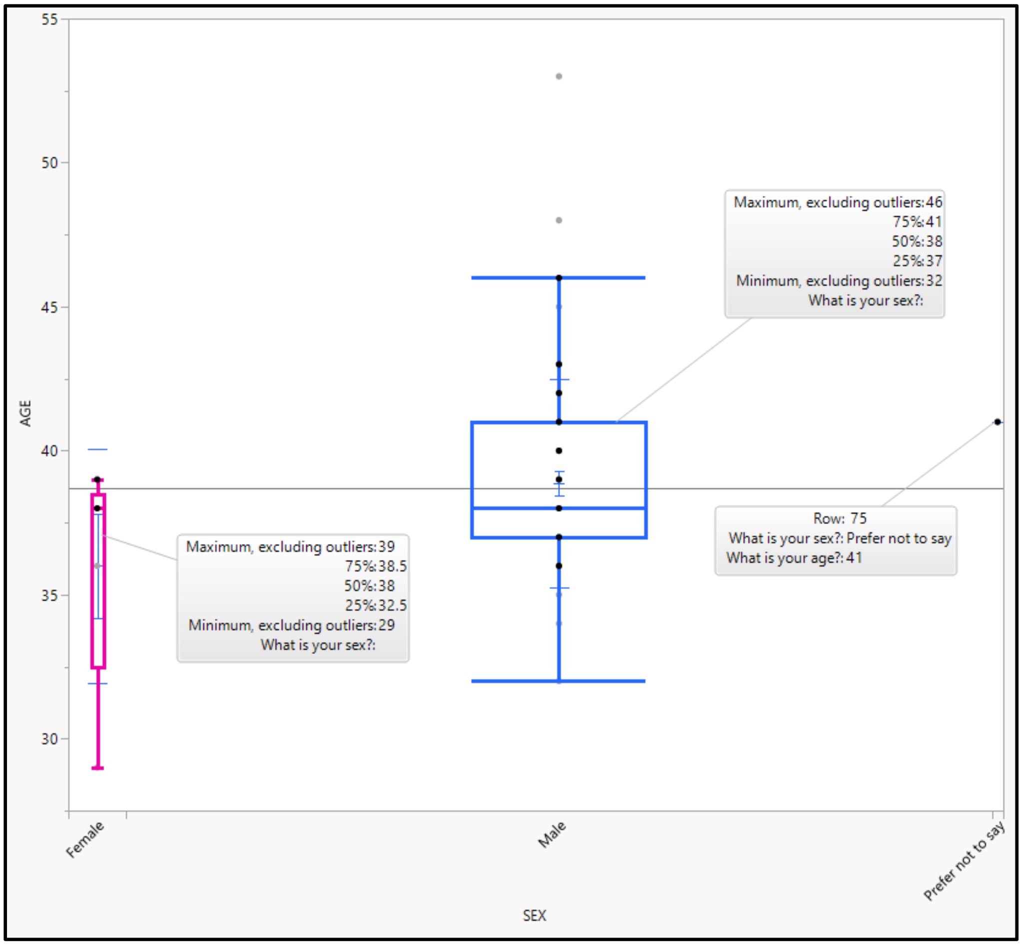


Figure 3. Participant ages by sex

C. OCCUPATIONAL CHARACTERISTICS

All participants were Officers in the U.S. Navy. The study sample included 1 (1%) Lieutenant, 41 (51%) Lieutenant Commanders, 37 (46%) Commanders, and 2 (2%) Captains. The numbers of years of service ranged from 7 to 34 years. The median years of service on active duty was 16 years (IQR = 4). All participants had completed at least two deployments. Although the maximum number of deployments reported was 15, the average number of deployments was 5.5. The median total number of months deployed was 30 months (IQR = 21.5). Deployments were averaged five months in length.

D. BEHAVIORAL CHARACTERISTICS AND DAILY ACTIVITY

Participants provided information about specific behaviors and daily habits related to overall well-being. Information requested included types and quantities of caffeinated beverages consumed daily and the types and frequency of nicotine or tobacco products used. Over the counter and prescription medications and the types and frequency of exercise or physical activity the participant engages in was also recorded. In general, 75 (93%) of the participants reported consuming at least one caffeinated beverage daily; 66 (88%) of them reported drinking coffee. The average number of servings or cups of coffee consumed per day was approximately 2.6 cups. Also, 13 (16%) of participants reported drinking at least 1 energy drink per day. Figure 4 depicts the cups of coffee consumed per day by participants.

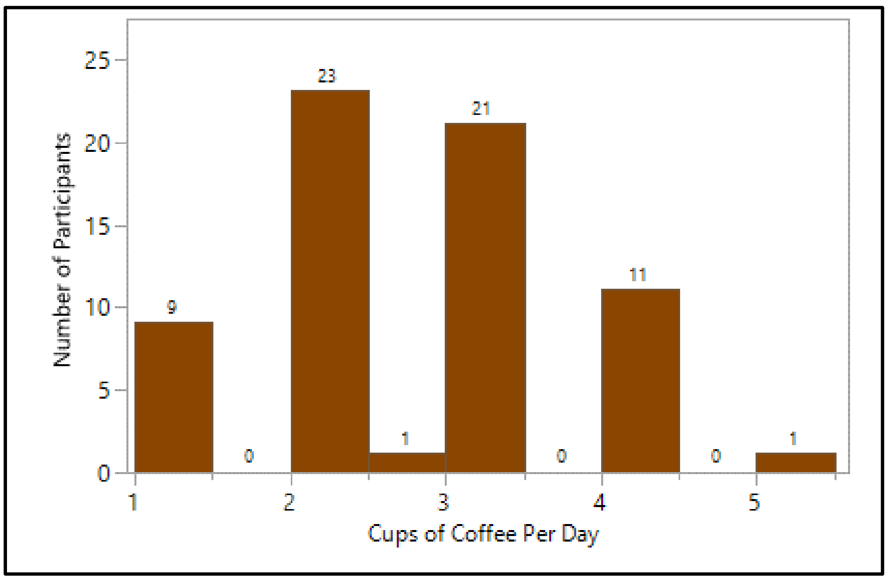


Figure 4. Daily consumption of coffee (cups per day)

Out of the 81 participants, 17 (21%) reported nicotine or tobacco use. Smoking, chewing tobacco, snuff, pipe tobacco, nicotine pouches, Nicorette gum or patches, and cigars were the types of nicotine and tobacco products reported. As for medications, 33 (41%) participants reported taking prescription or over-the-counter medications. Fourteen (42%) of the participants who reported taking medications reported taking antihistamines, whereas 8 (24%) participants reported taking antidepressant medications, high blood pressure medication, and/or testosterone-related drugs. Other medications included weight loss drugs, vitamins, and pain relievers (such as Motrin or Tylenol).

Twelve (15%) participants reported not having a regular exercise routine whereas 69 (85%) reported they did. Of the 69 participants, the average number of times per week an individual worked out was 4.5 times with a minimum of 2 times per week and a maximum of 8 times per week. All participants who engaged in exercise worked out between 30 minutes to 4 hours. Types of exercises within routines consisted of swimming, cycling, weightlifting, stair climbing, high intensity interval training, and rowing. Figure 5 shows the weekly distribution of physical activity frequency.

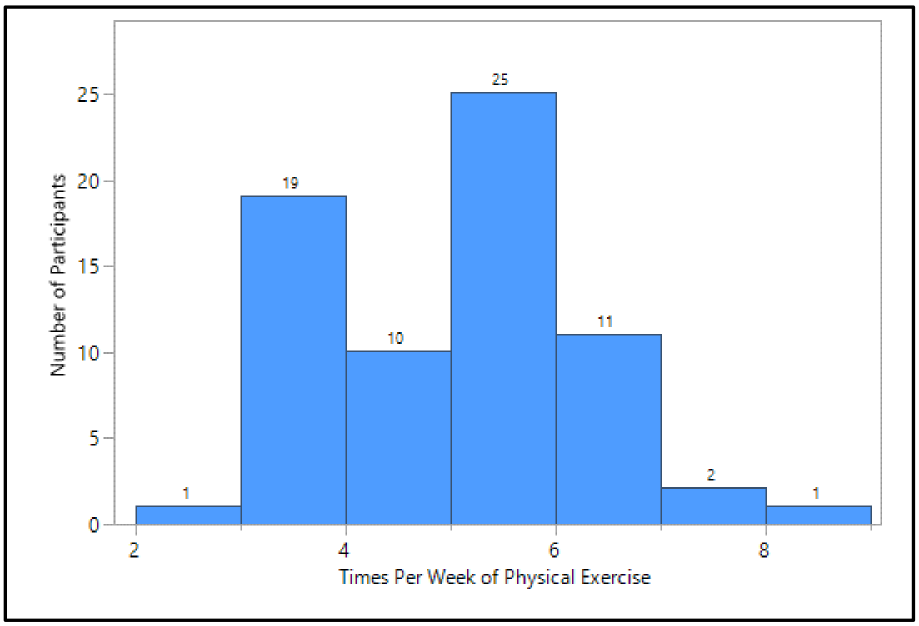


Figure 5. Frequency of physical exercise (times per week)

E. PATIENT HEALTH QUESTIONNAIRE (PHQ-8)

Figure 6 shows the distribution of the PHQ-8 scores. PHQ-8 scores ranged from 0 to 24 with a median of 2 (IQR = 3). “Normal,” “Major Depression,” and “Severe Major Depression” are the three categories participants were classified as falling into based on their PHQ-8 score. Figure 8 represents the participant break out by category. Only 1 (1%)

participant was classified as experiencing symptoms of "Major Depression" where the rest scored in the "Normal" category.

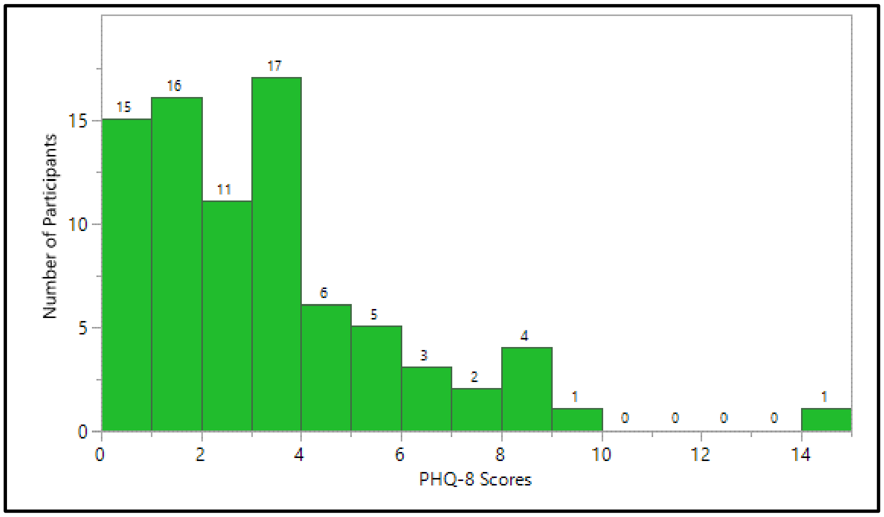


Figure 6. Distribution of PHQ-8 scores

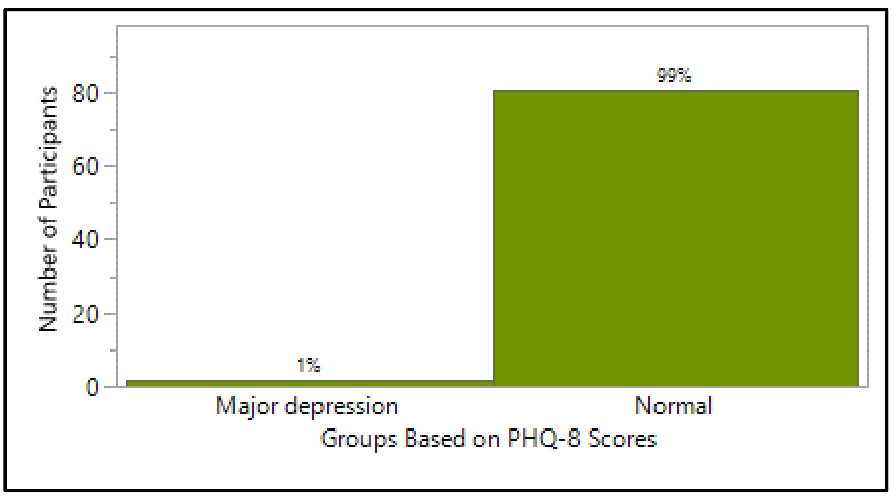


Figure 7. Participant groups based on PHQ-8 scores

F. PERCEIVED STRESS SCALE (PSS-10)

Figure 8 depicts the distribution of PSS-10 scores. The average PSS-10 score was 9.8 ± 6.2 ranging from 0 to 32. Based on their scores, participants were classified into one of three categories: low perceived stress (73% of the participants), moderate perceived stress (26%), and high perceived stress (1%). Participant groups based on their PSS-10 scores are shown in Figure 9.

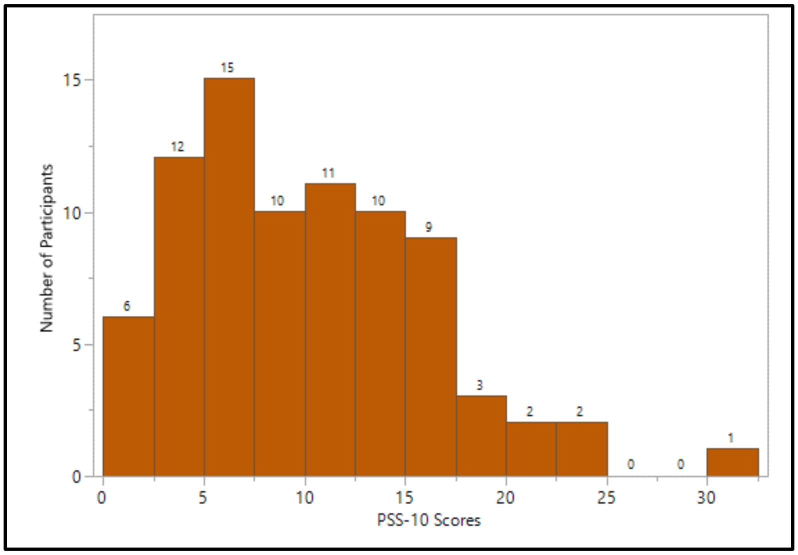


Figure 8. Distribution of PSS-10 scores

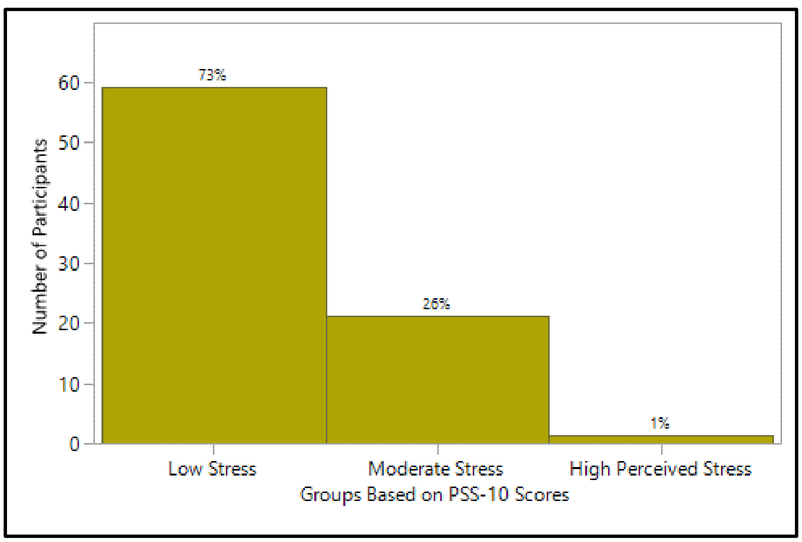


Figure 9. Participant groups based on PSS-10 scores

G. PROFILE OF MOOD STATES (POMS)

The average scores of the POMS scales and their corresponding ranges are shown in Table 3. Figure 10 shows the percentage of participants with POMS scores greater than the 50th percentile of the general adult population compared to the percentage of participants with scores below the 50th percentile. Of the 80 participants who completed the questionnaire, 31 (39%) participants had a Total Mood Disturbance (TMD) score greater than the 50th percentile. To interpret the POMS scores in Figure 10, if there is more green, the higher (better) the POMS scores. If the study population was equivalent to the normal population, approximately 50% of the study participants would have a score close to the 50th percentile. Visual inspection of the figure indicates that this study sample is overall similar or better compared to the general population of adults.

Table 3. Average POMS scores and ranges

POMS Scale	Score	Range
Tension-Anxiety	8.66	0-36
Depression	6.2	0-60
Anger-Hostility	5.7	0-48
Vigor-Activity	18.1	0-32
Fatigue	6.69	0-28
Confusion-Bewilderment	5.9	0-28
Total Mood Disturbance	15	-32-200

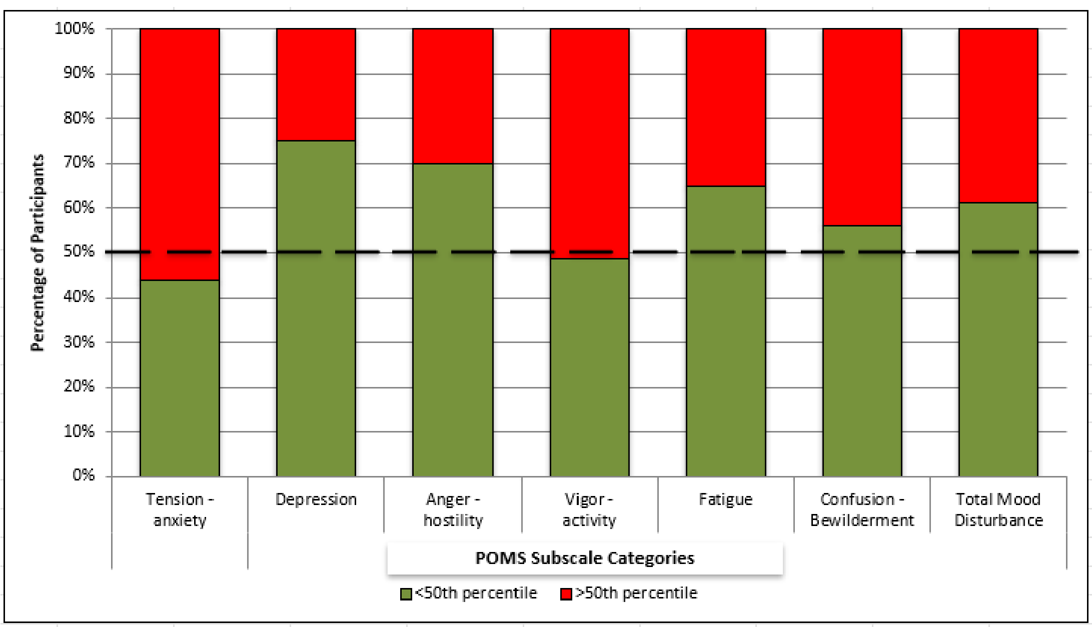


Figure 10. Participants' scores for POMS mood measurements

H. GENERAL ANXIETY DISORDER (GAD-7)

Participants had a median GAD-7 score of 2 (IQR = 3) ranging from 0 to 16. The distribution of GAD-7 scores is shown in Figure 11, with 61 (76%) senior leaders having a score less than a value of 5 meaning they had minimal anxiety. Based on their GAD-7 score, participants were classified into four generalized anxiety groups. As shown in Figure 12, 4 (5%) were classified as showing symptoms of "Moderate Anxiety" or "Severe Anxiety."

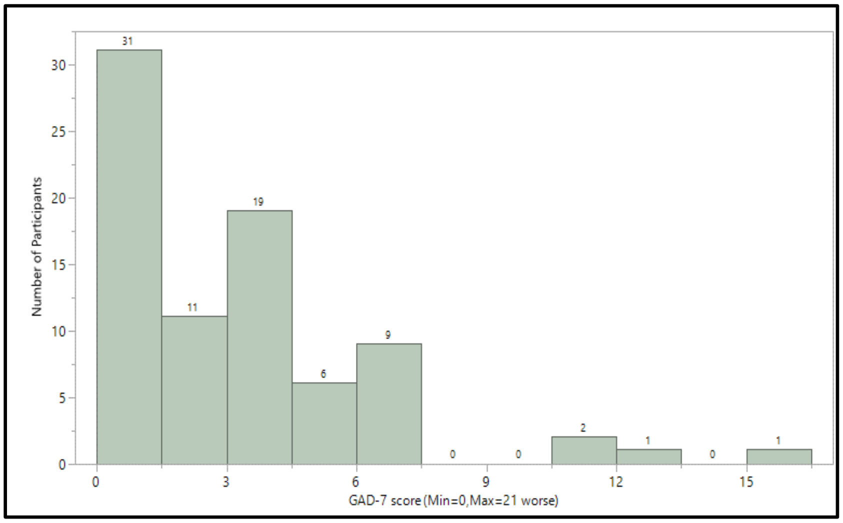


Figure 11. Distribution of GAD-7 scores

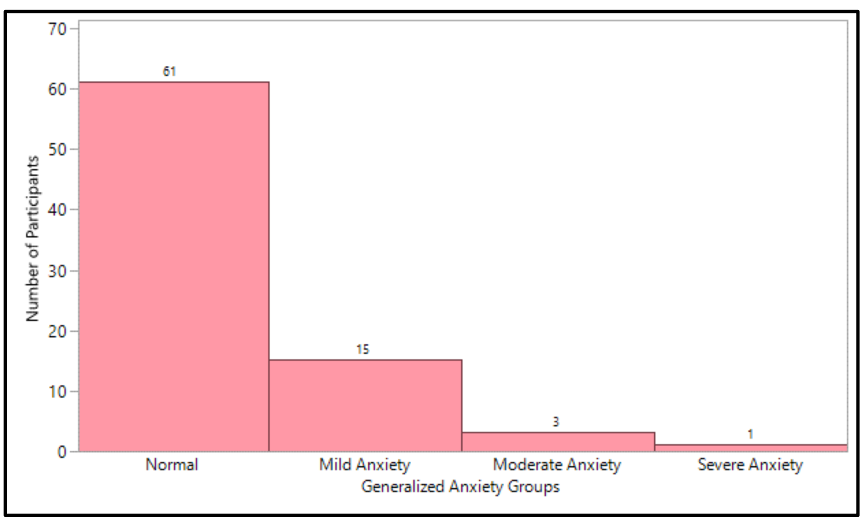


Figure 12. Counts of generalized anxiety groups

I. ŌURA DATA

The following subsections provide insights into each study period independently.

1. SWSC Period

Table 4 provides the descriptive statistics for the ŌURA variables of interest (data from 60 participants). Figure 13 shows the distribution of the mean total sleep time in hours.

Table 4. SWSC descriptive statistics

Variable	Mean	SD
ŌURA Sleep Score	78.49	6.05
Time in Bed Duration in Hrs	7.93	0.69
Total Sleep Time in Hrs	6.83	0.66
Efficiency, %	86.48	4.02
Restless, %	4.95	1.15

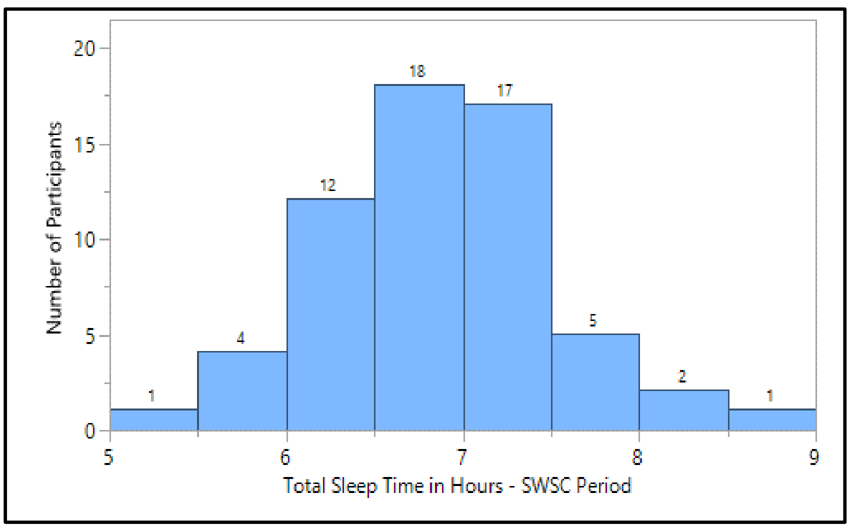


Figure 13. Total sleep time in hours during the SWSC period

2. Period between SWSC and Operational Command (Between Period)

ŌURA data were collected from only 43 participants during this period. Table 5 provides the descriptive statistics for the ŌURA variables. Figure 14 shows the distribution of the mean total sleep time in hours for the between period. This is an interesting period because there was not a set length of time between when a participant graduated from SWSC and when the individual checked into their operational command. During this period, senior leaders attend additional training (I-stops), check into a temporary command until it is time to report to their operational billet, or take leave.

Table 5. Between period descriptive statistics for means

Variable	Mean	SD
ŌURA Sleep Score	77.97	5.73
Time in Bed Duration in Hrs	7.93	0.67
Total Sleep Time in Hrs	6.80	0.65
Efficiency, %	85.85	3.83
Restless, %	4.80	1.05

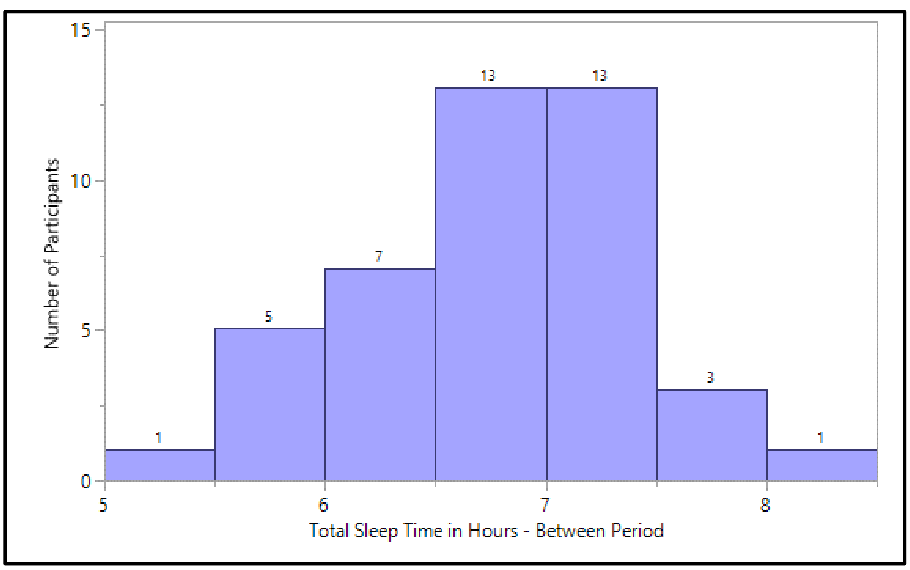


Figure 14. Total sleep time in hours during the between period

3. Operational Period

ŌURA data were collected from only 23 members during this period. Table 6 provides the descriptive statistics for the ŌURA variables. Figure 15 shows the distribution of the mean total sleep time in hours for the operational period.

Table 6. Operational period descriptive statistics for means

Variable	Mean	SD
ŌURA Sleep Score	78.03	5.32
Time in Bed Duration in Hrs	7.5	0.58
Total Sleep Time in Hrs	6.54	0.61
Efficiency, %	87.22	2.99
Restless, %	4.7	1.03

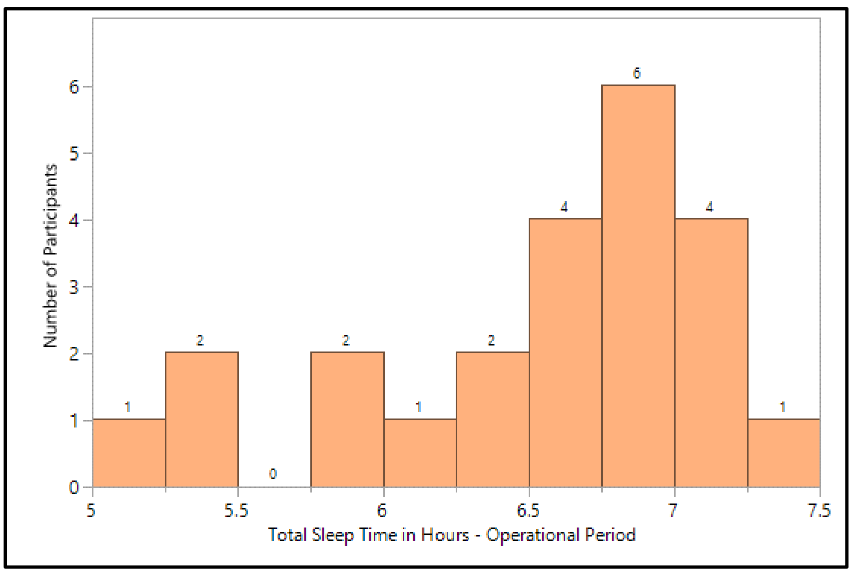


Figure 15. Total sleep time in hours during the operational period

4. Differences Amid Periods

To support answering the second research question (Do the sleep patterns and well-being vary according to location (e.g., schoolhouse versus an operational environment)?), we needed to establish if differences existed between the study periods. To do so, we used a mixed-effects model analysis. Results indicated that sleep duration differed among the study periods ($p = 0.012$).

Pairwise comparisons using the Wilcoxon Signed Rank test was used to establish which study period(s) differed. The pairwise comparisons showed that the duration of major sleep episodes differed between two of the three of the comparisons. First, we found a statistical significance between the Operational Period and the SWSC Period ($p = 0.009$). There was also statistical significance between the Operational Period and the Between Period ($p = 0.043$). These results showed that senior leaders had shorter major sleep episodes during the Operational Period compared to the other two periods (Figure 16). Each error bar in Figure 16 was constructed using one standard deviation from the mean. Due to small quantity of data available for participants across all three periods, only 12 participants were used to test if statistical significance existed between periods. Pairwise comparisons had more data available (up to 16 participants). Even though more data is needed to support in-depth analysis, the takeaway is that differences existed between periods.

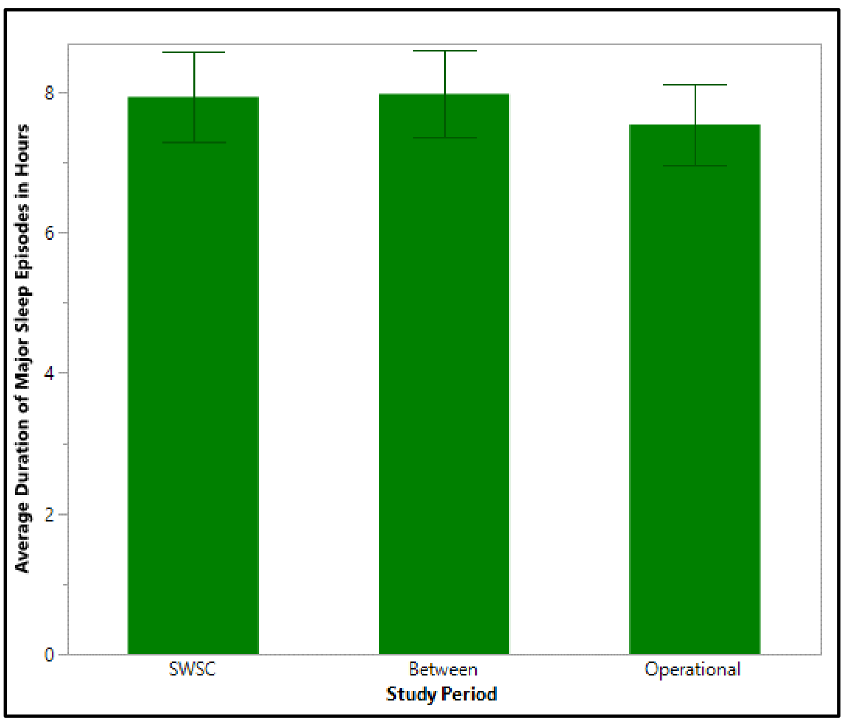


Figure 16. Average duration of major sleep episodes in hours

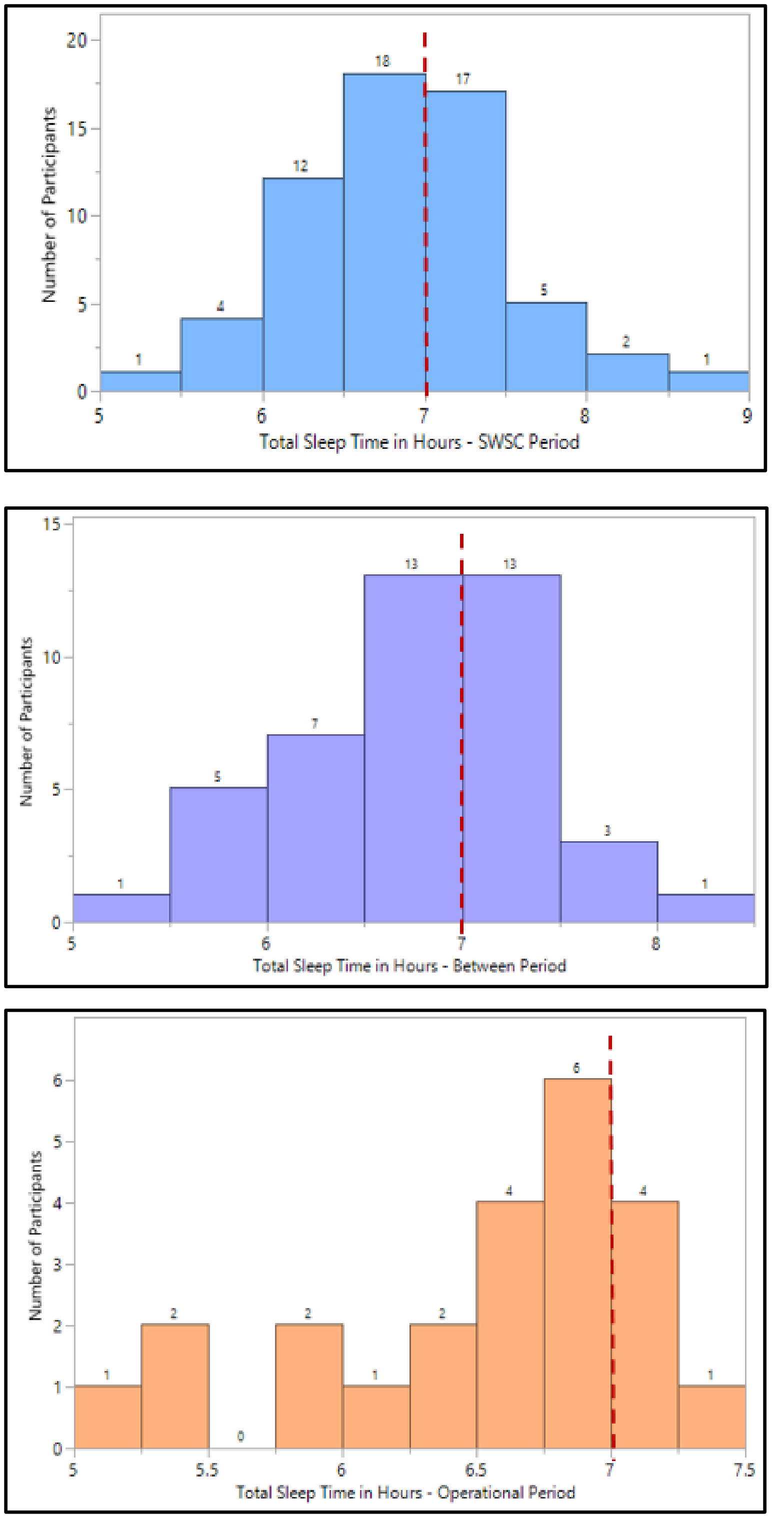
On the following page, Figure 17 represents a collage of Figures 13, 14, and 15 for ease of reference. On average, total sleep time (i.e., all sleep stages summed together) during the SWSC Period was higher with 25 (42%) of the 60 participants receiving seven hours of sleep or more. Participants in the Between Period received slightly less total sleep time with 17 (40%) out of 43 participants receiving seven hours or more of sleep. Although a larger sample size would be more definitive for the Operational Period, based on the number of participants whose data was available for analysis, total sleep time received was nearly half the amount of those periods where members are on some sort of set schedule. The average total sleep time for those in the Operational Period was less with only 5 (22%) of the 23 participants receiving seven hours or more of sleep.

J. ADDITIONAL ANALYSIS RESULTS

In addition to confirming differences exist between study periods and which periods are different, we were also concerned with identifying the most influential variables as well as identifying factors that may relate to the sleep and well-being of senior leaders. After calculating correlations among ages and questionnaire scores, comparisons between factors and sexes were analyzed. Additionally, factors and rank groups were also evaluated. A summary of the study's results can be viewed in Tables 7 and 8, respectively.

1. Correlations

Using the results from the initial questionnaires and after checking for normality, we explored correlations among Age, PHQ-8 scores, PSS-10 scores, POMS scales, TMD scores, and GAD-7 scores. We found none of the bivariate correlations that included Age to be statistically significant. In other words, Age was not a significant factor with respect to any of the questionnaire responses. However, significant correlations were noted among the questionnaire scores. These results were expected because of the similarities in the input values of the questionnaires and the relatively low variance in participants' age.



The red dotted line graphically highlights the recommended seven hours or more of sleep. Histograms are aligned to show the differences in study periods.

Figure 17. Total sleep time in hours for all periods.

2. Differences/Comparisons in Sex

Our next step in analysis was to explore the differences in sex (Table 7). The participant who did not disclose their sex was excluded from this analysis. The goal was to explore if differences exist between participant sexes and the variables of interest listed in Table 7.

ChiSquare values were calculated to establish the likelihood a variable of interest is or is not associated to a participant's sex. When the ratio is greater than one, this indicates that sex is associated with the variable of interest. Conversely, if the ratio is less than one, then the test result is not associated with the variable of interest. P-values were calculated to identify if there was statistical significance between the variable of interest and the sex of the participants.

Only five females responded to the questionnaires, which was inadequate data for concrete conclusions. However, we found some indications of sex differences. Females report taking more medicine than males who report using more tobacco products. Male and female exercise routines frequency did not differ. Almost all participants scored in the normal range on the PHQ-8 regardless of sex. Correlations between GAD-7 categories of anxiety and those taking medications were both variables of interest that warrant further investigation once additional data become available in the longitudinal project.

Table 7. Statistical significance and summary results of differences in sex

Variable of Interest	Females (# ; % of the total)	Males (# ; % of the total)	ChiSquare likelihood ratio	*p-value*	Statistical Significance of differences
Do you use tobacco products?	No: 5 100% Yes: 0 0%	No: 58 77.33% Yes: 17 22.67%	2.477	0.116	No
Do you take medications?	No: 1 20% Yes: 4 80%	No: 47 62.67% Yes: 28 37.33%	3.572	0.059	No, but almost statistically significant
Do you have an exercise routine?	No: 1 20% Yes: 4 80%	No: 11 14.67% Yes: 64 85.33%	0.097	0.756	No
PHQ-8 categories of depression	Normal: 5 ; 100%	Normal: 74 ; 98.67%	0.130	0.719	No
	Major Depression: 0 ; 0%	Major Depressions: 1 ; 1.33%			
PSS-10 categories of stress	Low: 3 ; 60%	Low: 56 ; 74.67	0.685	0.710	No
	Moderate: 2 ; 40:	Moderate: 18 ; 24%			
	High: 0 ; 0%	High: 1 ; 1.33%			
GAD-7 categories of anxiety	Normal: 4 ; 100%	Normal: 56 ; 74.67%	2.268	0.5188	No
	Mild: 0 ; 0%	Mild: 15 ; 20%			
	Moderate: 0 ; 0%	Moderate: 3 ; 4%			
	Severe: 0 ; 0%	Severe: 1 ; 1.33%			

3. Differences/Comparisons in Rank Groups

In this section we focus on differences with respect to rank groups. Group 1 consisted of O-3s and O-4s (42 participants). Group 2 consisted of O-5s and O-6s (39 participants). Unlike the disparity in group sizes between males and females in the previous section, the similar sizes of the rank groups support stronger analysis results. Table 8 shows the differences between participant rank groups and other variables of interest.

These findings indicate that the higher the participant's rank, the higher the likelihood of taking medication. Another observation was that Group 1 showed higher numbers of "Moderate Stress" than Group 2 according to the PSS-10 results although one participant in Group 2 scored in the "High Perceived Stress" range. Another difference we found between rank groups concerned anxiety. The GAD-7 results showed that Group 1 had higher numbers of participants with "Mild" anxiety while Group 2 had higher numbers of participants with "Moderate" or "Severe" anxiety. The majority of participants in both rank groups scored in the "Normal" range, indicating that senior Officers report more anxiety than junior Officers.

With regards to tobacco product usage and whether participants have an exercise routine, percentages of both rank groups were nearly the same. Approximately 20% of both groups reported using tobacco products and approximately 85% reported having an exercise routine. Although none of the comparisons were statistically significant, PSS-10 categories of stress and those who reported taking medications were both variables of interest that were closest to significance. In addition to these results, GAD-7 categories of anxiety and PHQ-8 depression scales had a score above one for the ChiSquare likelihood measure, meaning these four variables (PSS-10, GAD-7, PHQ-8, and medication use) would be recommended starting points for follow-on analysis.

Table 8. Statistical significance and summary results of differences in rank groups

Variable of Interest	Group1 O3/O4 (# and %)	Group2 O5/O6 (# and %)	ChiSquare likelihood ratio	*p-value*	Statistical Significance of differences
Do you use tobacco products?	No: 34 80.95% Yes: 8 19.05%	No: 30 76.92% Yes: 9 23.08%	0.198	0.656	No
Do you take medications?	No: 29 69.05% Yes: 13 30.95%	No: 19 48.72% Yes: 20 51.28%	3.484	0.062	No
Do you have an exercise routine?	No: 6 14.29% Yes: 36 85.71%	No: 6 15.38% Yes: 33 84.62%	0.019	0.889	No
PHQ-8 categories of depression	Normal: 42 ; 100%	Normal: 38 ; 97.44%	1.475	0.2245	No
	Major Depression: 0 ; 0%	Major Depressions: 1 ; 2.56%			
PSS-10 categories of stress	Low: 27; 64.29%	Low: 32; 82.05%	5.684	0.0583	No, but almost statistically significant
	Moderate: 15; 35.71%	Moderate: 6; 15.38%			
	High: 0 ; 0%	High: 1; 2.56%			
GAD-7 categories of anxiety	Normal: 29; 70.73%	Normal: 32; 82.05%	5.221	0.1563	No
	Mild: 11; 26.83%	Mild: 4; 10.26%			
	Moderate: 1; 2.44%	Moderate: 2; 5.13%			
	Severe: 0; 0%	Severe: 1; 2.56%			

V. DISCUSSION

A. CONCLUSIONS

Upon completion of training at SWSC, Officers are deployed to the fleet, to serve as leaders and are expected to maintain a high level of performance, even under the pressures of stressful, complex, and challenging operational environments. These senior leaders often work long shifts, surpassing the full-time work week (40 hour) standard. Making matters worse, senior leaders may not have a regular schedule, negatively impacting sleep quality and duration, which may result in fatigue, degraded cognitive function, and poor decision making. With this background in mind, this thesis assessed whether the measurements provided by commercially available ŌURA rings could provide insight into senior Officers' sleep quality, sleep patterns, and overall readiness. The research goal was to examine senior Officers' sleep patterns and well-being to determine if demographic, behavioral, and occupational characteristics could explain potential differences in these measures. The study used a longitudinal approach which was further divided into three periods: time at SWSC, the period between SWSC and the operational command, and time at the operational command.

To assist in answering the research questions, we attempted to accomplish four objectives. First, sleep/wake patterns and well-being (e.g., mood and daytime sleepiness) of senior leaders were assessed during three periods: at SWSC, between SWSC and prior to checking into the operational command, and after checking onboard to the operational command while performing regular duties. Second, the most influential variables during the periods were identified and assessed. Third, individual factors (e.g., age, sex), occupational factors (e.g., deployment duration, rank), and behavioral factors (e.g., caffeine intake, tobacco use) that may relate to the sleep and well-being of senior leaders were identified and analyzed. Lastly, recommendations are provided for future analysts to optimize readiness of senior leaders in the surface fleet.

1. Sleep

During the SWSC Period, we found that the mean total sleep time was 6.83 hours (SD = 0.65). Total sleep time decreased slightly during the Between Period with a mean of 6.80 hours (SD = 0.65) and further decreased during the Operational Period with a mean of 6.54 hours (SD = 0.61). Although it is notable that the total sleep time decreased in the Operational Period, participants across the board obtained less than the recommended seven or more hours of sleep to maintain optimal health in adults (Watson et al., 2015). Results also showed that the number of participants who averaged above seven hours per night of sleep decreased nearly 50% in the Operational Period, compared to the other two periods. Specifically, only 5 (22%) of the 23 participants obtained seven hours or more of sleep. This data supports our conclusion that when a senior leader does not have a set work schedule (like when in training during the SWSC Period or Between Period), his or her total sleep time greatly decreases.

2. Influential Variables and Factors

Influential variables in this study included total sleep time and sleep duration in hours. The mean sleep score, sleep efficiency percentage, and sleep restless percentage were consistent across all three periods, indicating they had less influence in the model. In addition to sleep quantity challenges that exist for senior leaders, results from questionnaires revealed that challenges also exist with sleep quality and mood. POMS scores showed that out of 80 participants, 31 (39%) participants had a total mood disorder score greater than the 50th percentile. As for the remaining questionnaires, the majority of participants' scores indicate positive mood and overall mental health. PHQ-8 depression scores for 99% of participants were in the normal range. Perceptions of stress, as indicated by PSS-10 scores, indicated 73% of participants scored in the "Low Stress" category. For anxiety, GAD-7 scores were skewed to the right with the majority (61.76%) of participants receiving normal results. Of note, these results were based on responses to a single questionnaire administered while participants were in training. If participants take this series of questionnaires more than once, future studies would have a much stronger basis for drawing conclusions.

Using pre-study questionnaire responses, we observed that 75 (93%) of the participants reported consuming at least one caffeinated beverage daily; 66 (88%) of them reported drinking coffee. The average number of servings or cups of coffee consumed per day was approximately 2.6 cups. Our analysis does not link caffeine intake directly to negative sleep impacts or the well-being of senior leaders; however, excessive use of caffeine may be an indication of fatigue and sleep debt. Additionally, 41% of participants reported taking medication of some sort, which may include medications that impact sleep (caffeine pills, prescription, etc.). Another observation is that 85% of participants reported having an exercise routine. Of the 69 participants who engage in physical activity, on average, individuals report working out 4.5 times per week. Having an exercise routine promotes good health and may positively impact sleep.

Bivariate correlations were examined for age and questionnaire scores. Dependent variables were then analyzed using comparisons with sexes and rank groups to identify the most influential variables during training. There were no correlations found to be statistically significant that included age. However, statistically significant correlations were noted among items on the various questionnaires. These correlations were not surprising because of the similarities in constructs assessed in the questionnaires and the low variance in participant ages.

Next, we compared sex to the variables of interest. Observations using Table 7 indicate that females took more medicine than males, and men were more likely to use tobacco products than females. We support future research that can gather data to attempt to link medicine or tobacco use to impacts on sleep.

After comparing groups of participants by sex, we looked at groups by rank. In general, the higher a participant's rank, the higher the likelihood a participant takes medication. With regards to tobacco product usage and whether participants have an exercise routine, percentages of both groups were nearly the same. Approximately 20% of both groups reported using tobacco products and approximately 85% reported having an exercise routine. Although none of the comparisons demonstrated statistical significance in either sex comparisons or rank group comparisons, some variables showed interesting patterns that warrant further investigation as more data become available. These variables

(PSS-10, GAD-7, PHQ-8, and medication use) would be a recommended starting place to conduct a deeper dive.

B. CONSTRAINTS, LIMITATIONS, AND ASSUMPTIONS

Because this study was the first attempt to analyze the data collected specifically on senior leaders, it was necessary to make certain assumptions and to abide by several constraints and limitations.

- Data During the Between Period – Data during the Between Period varied greatly because each participant in this period had different lengths of time between departing SWSC and checking into their operational command. Some senior leaders had only two days between SWSC graduation and checking into the operational command while others had many months in between (in some cases up to nearly a year).

- Data by Participant – Not all participants completed the pre-study questionnaire and not all participants had ŌURA data during the same periods. A large portion of participants only had data collected from the SWSC Period and/or Between Period. The smallest portion of data came from the Operational Period. At the time point in which this study focused, only 12 participants of the 79 participants had ŌURA data across all three periods.

- Time – The data collection window began in 2020 and ended November 2022. During this window, the number of available study participants (PXO students at SWSC) was finite. If it had been feasible to extend the study window, we would have expected more participants and therefore more data. Unfortunately, due to constraints of graduation and the time needed to consolidate and analyze the data, the size of our dataset was limited.

- Study Participation – The frequency of how often participants upload their data and how often they wore their devices was not controllable. Some study participants were much better (more consistent) than others. We encouraged data upload and ring wear with periodic e-mails.

- Pandemic – A portion of this study's data was collected during the COVID-19 pandemic. In our analysis we did not differentiate between pandemic and non-pandemic data.
- ŌURA Rings – Members were given different generations of the ŌURA rings (Generation 2 or 3). We treated data collected from either generation identically. The ring sizes are U.S. sizes ranging from size 6 to 13 and the size issued was based on preference versus size for fit. Additionally, some rings were lost or switched out with an individual's own purchased ring or device. Failure to charge the devices resulted in missing information as well when the device was removed due to physical activity (such as when weightlifting) or due to discomfort.
- Population – The majority of the senior leaders were male Officers.
- Sleep Metrics – Many other sleep metrics could be analyzed in additional to the metrics evaluated in this study.
- Pre-Study Questionnaire – The pre-study questionnaires which were completed during SWSC for participants using a web-based platform called Qualtrics and were only administered once.
- Deployments – Due to limited knowledge of whether or not a participant was actually deployed (underway) during the Operational Period, we were not able to conduct comparisons of sleep data collected while underway versus in port.

C. FUTURE DIRECTIONS AND STUDIES

Future iterations of this study have great potential. We recommend emphasis on collecting more data, especially during the Operational Period in a way that can separate data collected at sea versus in port. Regarding the questionnaires used, the data collected was informative and relevant to sleep but we recommend participants take the questionnaires more than once. Ultimately, the goal is to be able to optimize schedules of senior leaders on various classes of ships to maximize quality and duration of sleep.

D. SIGNIFICANCE AND LASTING IMPACTS

Senior leaders must be able to perform their job and perform it well (quickly, accurately, etc.). Physically, senior leaders may slow down significantly because of insufficient sleep, leading to missing critical events or failing to give them the attention required from a senior leader. The life of the ship and its members onboard are the responsibility of senior leaders; fatigue and deteriorated attention are all negative effects which can result in injury to self and others, increasing risk of mishaps.

Most Surface Warfare Officers will admit that poor sleep and ever-changing work schedule are a way of life. However, this thesis shows how differences exist from the time senior leaders are in school, between school and operational commands, and when fully operational. Additionally, certain factors such as medicine and caffeine consumption may play a role in these sleep habits.

Incorporating more data and using the methods and content in this thesis may advance the surface warfare community's awareness and one day influence scheduling and policy changes regarding senior Officers. Future efforts should attempt to identify best practices in senior Officer scheduling (especially COs and XOs), which maximize sleep schedule consistency and reduce sleep interruptions. Safeguarding sleep will improve senior Officer performance which in turn will improve the ship's readiness and the quality of life for all onboard. A leader must be afforded the opportunity to get adequate sleep and have the awareness and tools to mitigate the negative impacts of fatigue.

Referring to the last two lines of the U.S. Navy's Sailor's Creed, all U.S. Navy Sailors are Sailors first; in addition to serving the crew and other Sailors, the fair treatment of all includes the individual self. The importance of this topic cannot be emphasized enough. Keeping in mind the 17 service members lost in the 2017 collisions, if we can influence lasting change, perhaps we can improve the health and performance of all Sailors and prevent future tragedies.

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APPENDIX A. PRE-STUDY QUESTIONNAIRE

Date: ____________ Participant ID: ____________

Pre-study Questionnaire

Instructions: *Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.*

1. What is your age? ____________ years
2. What is your sex? ☐ Male ☐ Female
3. What is your height? ________ feet ________ inches
4. What is your weight? ______________________ lbs
5. What is your current position: (for example, police officer) ______________________________
6. How long have you been working in your current field: __________________________ years
7. During the last two weeks, how many of the following caffeinated beverages did you drink <u>on average</u> each day? (Check ALL that apply ☑) and indicate daily amount)
   - ☐ Tea — Servings/Cups per day: ______
   - ☐ Coffee — Servings/Cups per day: ______
   - ☐ Soda/pop/soft drinks — Servings/Cans per day:
   - ☐ Energy drinks — Servings/Cans per day:
   - ☐ Other (specify): ______________ How often: ______ (Example: 4 times per day)
8. Did you use nicotine or tobacco products during the last two weeks? (Check one ☑) ☐ Yes ☐ No

   If yes, which of the following nicotine or tobacco products do you use?
   (Check ALL that apply ☑ and indicate how often)
   - ☐ Cigarettes — If YES, how often? ____________
   - ☐ Chewing tobacco/snuff — If YES, how often? ____________
   - ☐ Nicorette gum or patches — If YES, how often? ____________
   - ☐ Electronic smoke — If YES, how often? ____________
   - ☐ Other (specify): ______________ How often? ____________
9. Did you take any prescribed or over-the-counter medications during the last two weeks? (Check one ☑) ☐ Yes ☐ No

   If YES, please list all medications you take: ____

   ____
10. Did you have an exercise routine during the last two weeks? (Check one ☑) ☐ Yes ☐ No

    If YES, frequency: ____Times per week (for example, 3 times per week)

    What kind of exercise routine did you do? (for example, cardio, weight lifting)

    ____

    How long did this routine take? (for example, 45 minutes) ________________________________

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APPENDIX B. PATIENT HEALTH QUESTIONNAIRE-8 (PHQ-8)

PHQ-8. Over the **last 2 weeks**, how often have you been bothered by any of the following problems? (circle **one** number on each line)

	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself, or that you are a failure, or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3

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APPENDIX C. PERCEIVED STRESS SCALE-10 (PSS-10)

PSS. The questions in this scale ask about your feelings and thoughts during the **last month**. In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer fairly quickly. That is, don't try to count up the number of times you felt a particular way; rather indicate the alternative that seems like a reasonable estimate.

	Never	Almost Never	Sometimes	Fairly Often	Very Often
I. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and stressed?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that happened that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

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APPENDIX D. GENERALIZED ANXIETY DISORDER-7 (GAD-7)

GAD-7. Over the **last 2 weeks**, how often have you been bothered by the following problems? (circle **one** number on each line)	Not at all	Several days	Over half the days	Nearly every day
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it's hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3

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LIST OF REFERENCES

Belenky, G. (1997, January). Sleep, sleep deprivation, and human performance in continuous operations. In *Joint Services Conference on Professional Ethics-JSCOPE, 97*, 1–16).

Borbély, A.A. (1982). Sleep regulation: Circadian rhythm and homeostasis. In: Ganten, D., Pfaff, D. (eds) *Sleep. Current topics in neuroendocrinolog*y, vol 1. Springer. https://doi.org/10.1007/978-3-642-68333-6_3

Borbély, A. A., Daan, S., Wirz-Justice, A., & Deboer, T. (2016). The two-process model of sleep regulation: A reappraisal. *Journal of Sleep Research*, *25*(2), 131–143.

Cajochen, C., Chellappa, S. L., & Schmidt, C. (2014). Circadian and light effects on human sleepiness–alertness. In *Sleepiness and human impact assessment* (pp. 9–22). Springer.

Cambridge Dictionary. (n.d.). Readiness. In *Cambridge dictionary*. Retrieved October 22, 2022, from https://dictionary.cambridge.org/us/dictionary/english/readiness

Cambridge Dictionary. (n.d.). Workload. In *Cambridge dictionary*. Retrieved October 8, 2022, from https://dictionary.cambridge.org/us/dictionary/english/workload

Carskadon, M.A., & Dement, W.C. (2011). Monitoring and staging human sleep. In M.H. Kryger, T. Roth, & W.C. Dement (Eds.), *Principles and practice of sleep medicine*, 5th edition, (pp 16–26). St. Louis: Elsevier Saunders.

Casner, S. M., & Gore, B.F. (2010). Measuring and evaluating workload: A primer (NASA/TM—2010-216395). https://matbfiles.larc.nasa.gov/Workload_Primer_TM_Final.pdf

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, *24*(4), 385–396.

Costa, G. (2015). Sleep deprivation due to shift work. *Handbook of Clinical Neurology*, *131*, 437–446. https://doi.org/10.1016/B978-0-444-62627-1.00023-8

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature*, *388*(6639), 235. https://doi.org/10.1038/40775

de Zambotti, M., Rosas, L., Colrain, I. M., & Baker, F. C. (2019). The sleep of the ring: Comparison of the ŌURA sleep tracker against polysomnography. *Behavioral Sleep Medicine*, *17*(2), 124–136. https://doi.org/10.1080/15402002.2017.1300587

Della Monica, C., Johnsen, S., Atzori, G., Groeger, J. A., & Dijk, D. J. (2018). Rapid eye movement sleep, sleep continuity and slow wave sleep as predictors of cognition, mood, and subjective sleep quality in healthy men and women, aged 20–84 years. *Frontiers in Psychiatry*, *9*, 255. https://doi.org/10.3389/fpsyt.2018.00255

Dement, W. C., & Vaughan, C. (1999). *The promise of sleep.* Delacorte.

Department of the Navy. (2017). *Comprehensive fatigue and endurance management policy (COMNAVSURFPAC/COMNAVSURFLANT Instruction 3120.2)* Retrieved from https://federalnewsnetwork.com/wp-content/uploads/2017/12/113017_navyrestpolicy.pdf

Department of the Navy. (2020). *Comprehensive fatigue and endurance management policy (COMNAVSURFPAC/COMNAVSURFLANT Instruction 3120.2A)* Retrieved from https://www.navy.mil/Press-Office/News-Stories/Article/2453206/naval-surface-forces-releases-comprehensive-endurance-fatigue-management-progra/

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature reviews. Neuroscience*, *11*(2), 114–126. https://doi.org/10.1038/nrn2762

Fang, Z., & Rao, H. (2017). Imaging homeostatic sleep pressure and circadian rhythm in the human brain. *Journal of Thoracic Disease*, *9*(5), E495–E498. https://doi.org/10.21037/jtd.2017.03.168

Farhud, D., & Aryan, Z. (2018). Circadian rhythm, lifestyle and health: A narrative review. *Iranian Journal of Public Health*, *47*(8), 1068–1076.

Feinberg, I., & Floyd, T. C. (1979). Systematic trends across the night in human sleep cycles. *Psychophysiology*, *16*(3), 283–291. https://doi.org/10.1111/j.1469-8986.1979.tb02991.x

Government Accountability Office (GAO). (2017, May). *Navy force structure: Actions needed to ensure proper size and composition of ship crews* (GAO Publication 17–413). Washington, DC: U.S. Government Printing Office.

Government Accountability Office (GAO). (2021, May). *Navy readiness: Additional efforts are needed to manage fatigue, reduce crewing shortfalls, and implement training* (GAO Publication 21–366). Washington, DC: U.S. Government Printing Office.

Ha, M. & Park, J. (2005), Shiftwork and metabolic risk factors of cardiovascular disease. *Journal of Occupational Health*, *47*, 89–95. https://doi.org/10.1539/joh.47.89

Harrison, Y., & Horne, J. A. (2000). The impact of sleep deprivation on decision making: A review. *Journal of Experimental Psychology*, *6*(3), 236–249.

How, J. M., Foo, S. C., Low, E., Wong, T. M., Vijayan, A., Siew, M. G., & Kanapathy, R. (1994). Effects of sleep deprivation on performance of Naval seamen: I. Total sleep deprivation on performance. *Annals of the Academy of Medicine, Singapore*, *23*(5), 669–675.

Killgore, W. D. (2010). Effects of sleep deprivation on cognition. *Progress in Brain Research*, *185*, 105–129.

King, D. (2012). *NPS Concludes Sleep Study aboard Jason Dunham* (Story No. NNS121222-01). Federal Information & News Dispatch, LLC. http://www.navy.mil/submit/display.asp?story_id=71230

Knutsson, A., & Bøggild, H. (2010). Gastrointestinal disorders among shift workers. *Scandinavian Journal of Work, Environment & Health*, *36*(2), 85–95. https://doi.org/10.5271/sjweh.2897

Kroenke, K., Strine, T. W., Spitzer, R. L., Williams, J. B., Berry, J. B., & Mokdad, A. H. (2009). The PHQ-8 as a measure of current depression in the general population. *Journal of Affective Disorders, 114*(1-3), 163–173. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Kryder, C. (2022, September 10). *How does the Oura ring track my sleep?* ŌURA Ring & App. https://ouraring.com/blog/how-does-the-oura-ring-track-my-sleep/

Ma, N., Dinges, D. F., Basner, M., & Rao, H. (2015). How acute total sleep loss affects the attending brain: a meta-analysis of neuroimaging studies. *Sleep*, *38*(2), 233–240. https://doi.org/10.5665/sleep.4404

Matsangas, P., & Shattuck, N. L. (2020). Sleep quality, occupational factors, and psychomotor vigilance performance in the U.S. Navy sailors. *Sleep*, *43*(12), zsaa118. https://doi.org/10.1093/sleep/zsaa118

McNair, D.M., Lorr., & Droppelman, L. F. (1971). *Manual of the profile of mood states.* San Diego, CA: Educational and Industrial Testing Service.

Meltzer, L. J., Walsh, C. M., Traylor, J., & Westin, A. M. L. (2012). Direct comparison of two new actigraphs and polysomnography in children and adolescents. *Sleep*, *35*, 159–166.

Miller, J. (2008). Fundamentals of shiftwork scheduling. *Ergonomics in Design: The Quarterly of Human Factors Applications, 16(3),* 13–17. https://doi.org/10.1518/106480408X333109

Naval History and Heritage Command. (2018, October 16). *The Sailor's creed*. https://www.history.navy.mil/browse-by-topic/heritage/customs-and-traditions0/the-sailor-s-creed.html

Naitoh, P., Kelly, T. L., & Englund, C. (1990). Health effects of sleep deprivation. *Occupational Medicine (Philadelphia, Pa.). 5*(2):209-237. PMID: 2203156.

National Alliance on Mental Illness (2016). *Bupropion (Wellbutrin)*. The American Association of Psychiatric Pharmacists (AAPP). https://www.nami.org/About-Mental-Illness/Treatments/Mental-Health-Medications/Types-of-Medication/Bupropion-(Wellbutrin)

Nyenhuis, D. L., Yamamoto, C., Luchetta, T., Terrien, A., & Parmentier, A. (1999). Adult and geriatric normative data and validation of profile of mood states. *Journal of Clinical Psychology*, 55, 79–86.

Office of the Chief of Naval Operations. (2017, May 15). *Standard Organization and Regulations of the U.S. Navy* (OPNAVINST 3120.32D). Department of the Navy. https://www.secnav.navy.mil/doni/Directives/03000%20Naval%20Operations%20and%20Readiness/03-100%20Naval%20Operations%20Support/3120.32D%20W%20CH-1.pdf

Olsen, O. K., Pallesen, S., & Jarle, E. (2010). The impact of partial sleep deprivation on moral reasoning in military officers. *Sleep*, *33*(8), 1086–1090. https://doi.org/10.1093/sleep/33.8.1086

Ōura Health Oy (2020, September 2). *Your Oura readiness score*. The Pulse Blog. https://ouraring.com/blog/readiness-score/

Ōura Health Oy (2023). *Bring research full circle*. Empower Your Organization with Oura. https://ouraring.com/business

Patel, A. K., Reddy, V., Shumway, K. R., & Araujo, J. F. (2022, September 7). *Physiology, Sleep Stages*. Physiology, Sleep Stages – StatPearls – NCBI Bookshelf. Retrieved January 25, 2023, from https://www.ncbi.nlm.nih.gov/books/NBK526132/

NCBI Bookshelf. A service of the National Library of Medicine, National Institutes of Health.

Patke, A., Murphy, P. J., Onat, O. E., Krieger, A. C., Özçelik, T., Campbell, S. S., & Young, M. W. (2017). Mutation of the human circadian clock gene CRY1 in familial delayed sleep phase disorder. *Cell*, *169*(2), 203–215.e13. https://doi.org/10.1016/j.cell.2017.03.027

Razykov, I., Ziegelstein, R. C., Whooley, M. A., & Thombs, B. D. (2012). The PHQ-9 versus the PHQ-8--is item 9 useful for assessing suicide risk in coronary artery disease patients? Data from the Heart and Soul Study. *Journal of Psychosomatic Research*, *73*(3), 163–168. https://doi.org/10.1016/j.jpsychores.2012.06.001

Reed, D. L., & Sacco, W. P. (2016). Measuring sleep efficiency: What should the denominator be? *Journal of clinical sleep medicine (JCSM), Official Publication of the American Academy of Sleep Medicine*, *12*(2), 263–266. https://doi.org/10.5664/jcsm.5498

Rupp, T. L., & Balkin, T. J. (2011). Comparison of motionlogger watch and actiwatch actigraphs to polysomnography for sleep/wake estimation in healthy young adults. *Behavior Research Methods*, *43*, 1152–1160.

Sateia M. J. (2014). International classification of sleep disorders-third edition: highlights and modifications. *Chest*, *146*(5), 1387–1394. https://doi.org/10.1378/chest.14-0970

Shattuck, N.L., Matsangas, P., & Dahlman, A.S. (2018). Sleep and fatigue issues in military operations. In E. Vermetten, A. Germain, & T. Neylan (Eds.), Sleep and Combat related PTSD (pp. 69–76). New York, NY: Springer

Shattuck, N.L., & Matsangas, P. (2019). *Assessment of the utility of circadian-based watchstanding schedules for sailors working on the U.S. Navy surface ships*. (Technical Report No. NPS-OR-19-001R). Monterey, CA: Naval Postgraduate School.

Shattuck, N., Matsangas, P., Mysliwiec, V., & Creamer, J. (2019). *The role of sleep in human performance and well-being* (pp. 200–233). https://doi.org/10.1093/oso/9780190455132.003.0010

Shattuck, N., Matsangas, P., & Waggoner, L. (2014). Assessment of a novel watchstanding schedule on an operational U.S. Navy vessel. *Human Factors and Ergonomics Society Annual Meeting Proceedings*, *58*, 2265–2269. https://doi.org/10.1177/1541931214581472

Shattuck, N., Shattuck, L., & Matsangas, P. (2011). Sleep and fatigue issues in continuous operations: A survey of U.S. Army Officers. *Behavioral Sleep Medicine*, *9*, 53–65. https://doi.org/10.1080/15402002.2011.533994

Shay, J. (1998). Ethical standing for commander self-care: The need for sleep. *The U.S. Army War College Quarterly: Parameters*, *28*(2). https://doi.org/10.55540/0031-1723.1882

Skornyakov, E., Shattuck, N. L., Winser, M. A., Matsangas, P., Sparrow, A. R., Layton, … Van Dongen, H. P. A. (2017). Sleep and performance in simulated Navy watch schedules. *Accident Analysis & Prevention*, *99*, 422–427. https://doi.org/10.1016/j.aap.2015.11.021

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097. doi: 10.1001/archinte.166.10.1092

U.S. Government Publishing Office. (2017, September 19). *Senate Hearing 115–733*. – Recent U.S. Navy Incidents at Sea. Retrieved October 9, 2022, from https://www.govinfo.gov/content/pkg/CHRG-115shrg38896/html/CHRG-115shrg38896.htm

Under Secretary of Defense. (2021). *Study on effects of sleep deprivation on readiness of members of the Armed Forces*. https://www.health.mil/Reference-Center/Reports/2021/02/26/Study-on-Effects-of-Sleep-Deprivation-on-Readiness-of-Members-of-the-Armed-Forces-Final-Report

Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., Buysse, D., … Tasali, E. (2015). Recommended amount of sleep for a healthy adult: A joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. *Sleep*, *38*(6), 843–844. https://doi.org/10.5665/sleep.4716

Williamson, A. M., & Feyer, A.-M. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine (London, England), 57*(10), 649–655. https://doi.org/10.1136/oem.57.10.649

Xie, Y., Tang, Q., Chen, G., Xie, M., Yu, S., Zhao, J., & Chen, L. (2019). New insights into the circadian rhythm and its related diseases. *Frontiers in Physiology, 10*(682), 1–19. https://doi.org/10.3389/fphys.2019.00682

Zaki, N. F. W., Spence, D. W., Subramanian, P., Bharti, V. K., Karthikeyan, R., BaHammam, A. S., & Pandi-Perumal, S. R. (2020). Basic chronobiology: What do sleep physicians need to know? *Sleep Science, 13*(4), 256–266. https://doi.org/10.5935/1984-0063.2020002

Zhu, L., & Zee, P. C. (2012). Circadian rhythm sleep disorders. *Neurologic clinics*, *30*(4), 1167–1191. https://doi.org/10.1016/j.ncl.2012.08.011

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