

The Role of Sleep in the Military:
Implications for Training and Operational Effectiveness
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Abstract

This chapter addresses the role of sleep in a variety of military settings, ranging from military education and training regimes and extending to military missions and combat operations. It first overviews the scientific literature related to sleep and performance. It then describes a 10-year series of studies conducted at the Naval Postgraduate School that addresses fatigue and sleep restriction in military settings. These studies examine sleep patterns of Sailors aboard warships and submarines; shift the timing of sleep during training in Navy Recruits and Army Basic Combat Trainees; follow Cadets at the United States Military Academy at West Point in a 4-year longitudinal study; and assess sleep in operational environments including surveys of warfighters while deployed and recently returned from combat in Southwest Asia. Results of many of these studies are reviewed, concluding with recommendations advocating the inclusion of sleep as a factor when calculating military effectiveness.

Keywords: Sleep restriction, sleep deprivation, human performance, fatigue, military operations, military training, military education.

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Introduction

Military operations span a wide spectrum ranging from basic military training and education, through military operations other than war (MOOTW), to war itself. By their very nature, military operations are conducted under tremendously stressful conditions. Individuals in military settings are under pressure to continue to conduct operations when quality sleep may be a rare commodity—and sometimes, they are asked to perform without any sleep at all. Their duties expose them to life-and-death situations in environmentally hostile conditions that may even include facing down enemy combatants. While the impact of fatigue is not restricted to the military, the combined effects of a multitude of acute and chronic stressors—including severe sleep restriction—make the military population both unique and relevant to study when exploring the range and limits of human performance.

An Overview of Sleep

This first section of the chapter provides the rationale and scientific justification for the entirety of the program of research that follows. It begins with a discussion of circadian rhythms and the requirement for sleep in humans. It then provides a short tutorial on sleep architecture that describes the function and purpose of various stages of sleep. This introductory sleep overview concludes with a summary of the effects of restricted sleep on various kinds of human performance.

Circadian Rhythms and Requirements for Sleep in Humans

Human alertness waxes and wanes in a highly predictable manner over the course of a 24-hour day. Known as the circadian cycle, this pattern occurs naturally and is represented in a diurnal pattern of sleep and wakefulness. Many other physiological

parameters are aligned with this same circadian rhythm. For example, core body temperature and hormones such as melatonin, cortisol, human growth hormone (HGH), and the more recently discovered hormones, leptin and ghrelin, are known to have circadian patterns of release and action. Together, these hormones have a huge impact on human performance, mediating sleep and wakefulness as well as growth and cellular repair, hunger, and satiation. Although science discovers more every day about the contributions of these hormones, it is evident from our current knowledge that they are vital to our physical and mental health and well-being.

In his autobiographical account of the first nonstop, trans-Atlantic flight, Charles Lindbergh (1953) wrote:

“My mind clicks on and off...I try letting one eyelid close at a time while I prop the other open with my will, but the effort is too much. Sleep is winning. My whole body argues dully that nothing—nothing that life can attain, is quite so desirable as sleep. My mind is losing resolution and control.”

Despite efforts to refrain from sleeping, our bodies require it just as we require food and water. As humans, approximately a third of our life is spent asleep. For the most part, humans have adapted to the standard 24-hour day, although research conducted in temporal isolation facilities shows that without light or other cues such as exposure to light, mealtimes, and daytime sounds, many humans have an innate 24.50- to 25.00-hour clock (Horne, 1988). Horne (1988) defines sleep as “the rest and recovery from the wear and tear of wakefulness.” Sleep and sleep deprivation have been studied for decades—yet sleep remains a mysterious, but vital, requirement for life to be sustained. If deprived of sleep for longer than 14 days, humans will die (Coren, 1997).

There is almost universal acknowledgement that healthy adult humans require approximately eight hours of sleep each night for full cognitive functioning (Anch, Browman, Mitler, & Walsh, 1988). However, it is also recognized that there is considerable variability among individuals with some requiring more and some less than eight hours of sleep per night (Van Dongen & Dinges, 2000). Not only are there differences between individuals in sleep requirements, but there are also fairly predictable changes in sleep patterns that occur within an individual over the course of a lifetime. Figure 1 illustrates the changes in sleep patterns that are seen over a typical lifespan.

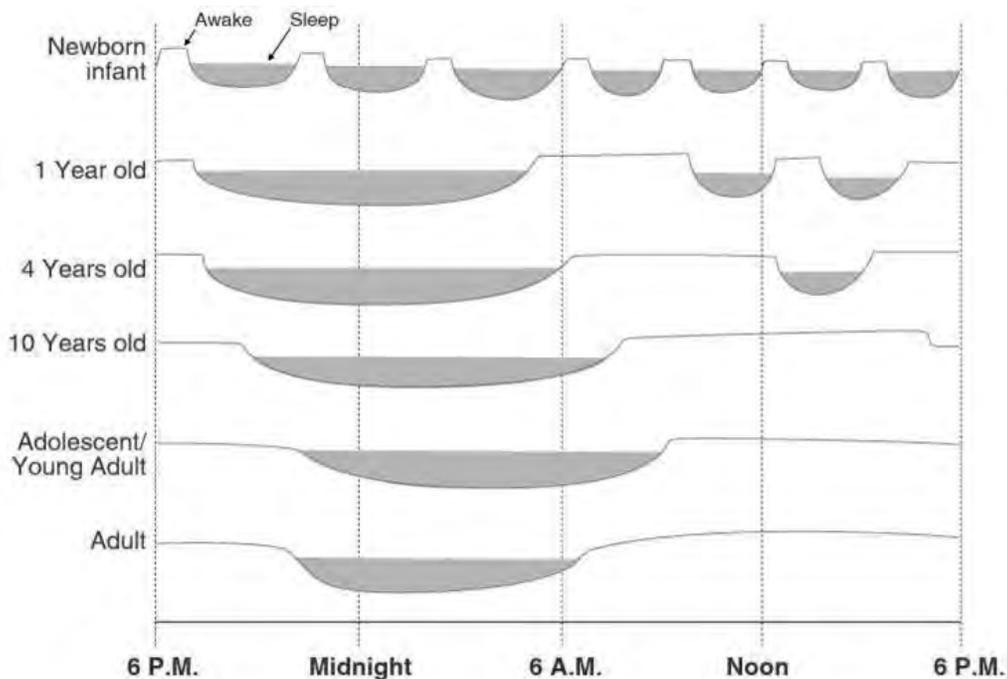


Figure 1. Sleep patterns over a typical lifespan (N. L. Miller, Matsangas, & Shattuck, 2008).

As can be seen, newborn infants have highly disrupted sleep patterns and generally get little contiguous sleep. To the great relief of their parents, most infants are sleeping through the night by the time they reach one year of age. Napping, a practice common in

babies and young children, tends to disappear as children reach elementary school age. In adolescents and young adults through the mid-20s, there is another interesting shift in sleep patterns. This age group actually requires approximately 0.50 to 1.25 hours more sleep per night than do their adult counterparts. Coinciding with the pattern of melatonin release in this age group, bedtime is delayed with even later awakenings (Carskadon, 2002; Carskadon, Wolfson, Tzischinsky, & Acebo, 1995; Wolfson & Carskadon, 1998, 2003). This change is important for the discussion of sleep in the military since many military service members, especially junior enlisted and junior officer personnel, are still in this adolescent and young adult sleep category and consequently require from 8.50 to 9.25 hours of sleep per night (N. L. Miller & Shattuck, 2005). By the time individuals reach their mid-20s—and continuing through their middle age years—sleep requirements are fairly stable at around eight hours per night.

Sleep Architecture in Humans

At one time, it was thought that nothing happened in the brain during sleep. However, it is now known that there are times in which the sleeping brain is more active than during its waking state. While asleep, it is impossible to monitor our own behavior. Consequently, over the years, scientists have developed various techniques (e.g., polysomnography or PSG) to gain insight into the activities of the sleeping brain. This technique includes measuring the electrical activity at the surface of the brain using electroencephalographic (EEG) electrodes placed on the scalp (Kryger, Roth, & Dement, 2000). During PSG procedures, electrodes also capture the respiratory patterns and muscle activity that occurs during sleep.

Recordings show that over the course of a typical 8-hour sleep period, the human brain experiences two broad categories of sleep: nonrapid eye movement (NREM) and rapid eye movement (REM). These two sleep categories have different functions and are characterized by distinctive behaviors. NREM sleep can be further divided into five sleep stages: Stage 0 (the awake state) and four progressively deeper sleep stages (Stage 1 through Stage 4). Typical sleep stages over the course of a night's sleep are illustrated in Figure 2.

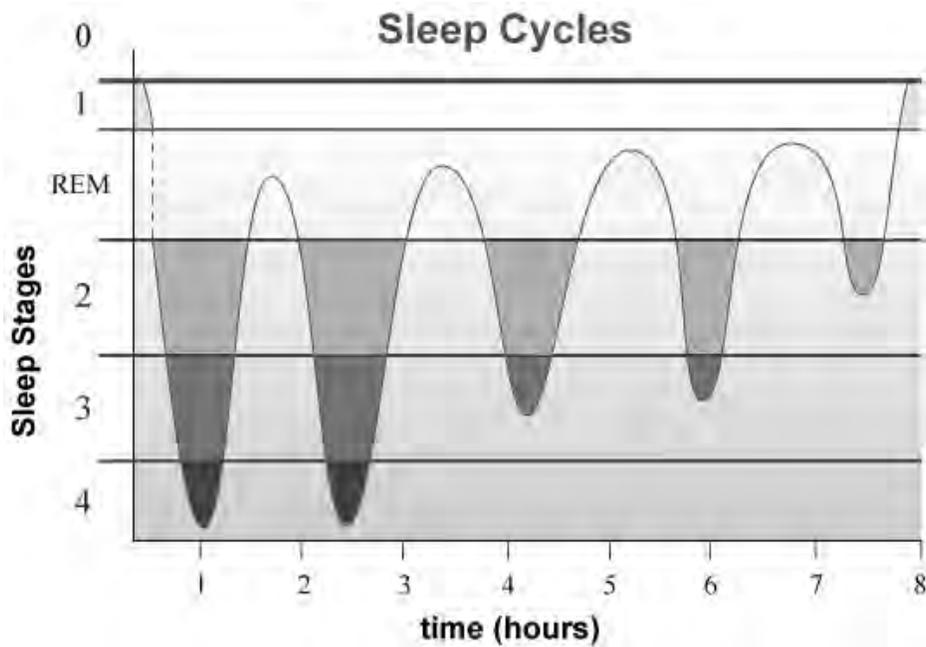


Figure 2. Sleep stages over a typical 8-hour sleep period (N. L. Miller et al., 2008).

As shown in Figure 2, all of these sleep stages are generally experienced over a single sleep cycle that lasts approximately 90 minutes. Research has demonstrated that much of the first half of an 8-hour, contiguous night of sleep is spent in deeper sleep (Stages 3 and 4), while Stages 1 and 2 and REM sleep are more prevalent in the latter half of an 8-hour sleep period.

Both REM and NREM sleep are necessary for normal functioning in humans. In a sleep laboratory, humans can be deprived of a single stage of sleep, known as partial sleep deprivation or PSD. When the sleep-deprived individual is allowed to sleep following PSD, the body tends to rebound into the sleep stage from which it was deprived, in an attempt to make up for the lost sleep. Total sleep deprivation, or TSD, is when the research participant is not allowed to sleep at all. When allowed to sleep after experiencing TSD, the body rebounds by rapidly entering deep stages of sleep that render the brain almost unconscious, reminiscent of brain activity under anesthesia. When sleepers are awakened from deep sleep stages, they frequently experience sleep inertia, characterized by reduced alertness and cognitive functioning. While sleep inertia is a normal occurrence upon awakening from a normal night's sleep, it may last much longer when a sleeper is awakened from deep stages of sleep. In operational environments where humans are deprived of adequate amounts of deep sleep, both conditions—the rebound into deeper sleep stages and the resultant sleep inertia when awakened from deep sleep—pose significant risks to the military member and those who rely on them to make good decisions and perform effectively under time pressure.

The Effects of Sleep Deprivation on Human Performance

The scientific literature shows clearly that sleep has a dramatic effect on human performance in laboratory settings. Countless studies have identified the deleterious effect of sleep deprivation on a wide range of human cognitive functions such as attention, memory, mood, and decision making (Broughton & Ogilvie, 1992; Dinges & Kribbs, 1991; Dinges et al., 1997). These studies are well-controlled trials that provide convincing results of changes that occur with sleep restriction—in the laboratory.

However, in the military and other related professions, there is often a reluctance to accept such laboratory findings, asserting that motivation and determination will allow individuals to perform in real-world environments despite fatigue and lack of sleep (Shay, 1998). Sleep debt seems ubiquitous in the military, despite policies that emphasize the importance of sleep and fatigue management for the operational readiness of units deployed to combat environments (Department of the Army, 2009; Department of the Navy, 2007). As history has taught us, lapses in attention and poor decisions made by members of our armed forces can have serious and far-reaching consequences. It is for these reasons that research must extend into naturalistic environments to observe the consequences of chronic and acute sleep deprivation during actual operations and to challenge the notion that these individuals are immune from performance decrements due to sleep loss.

Sleep Studies in Operational Environments at the Naval Postgraduate School

The United States military has long been interested in human performance in operational environments. It is not surprising that many studies conducted in the Operations Research Department at the Naval Postgraduate School (NPS) focus on such issues. Over the past decade, a group of NPS faculty and graduate students has been actively studying human performance as it relates to sleep in operational settings. Tables 1 through 3 list many of these operational studies and thesis efforts, the name of the primary investigator (often an NPS graduate student), the date the thesis or report was published, the focus of the investigation, and a summary of the findings with respect to sleep. The remainder of this chapter is divided into three sections according to these

tables: Sleep in Naval Operations, Sleep in Training and Educational Environments, and Sleep in Combat and Operational Environments. Many of the findings from these studies are reviewed in the three sections that follow. The chapter then concludes with a discussion of the overall findings from these studies of sleep in military settings.

Table 1: NPS Sleep Studies in Naval Operation

Naval Vessel	Mission (Length of Study)	Participants	Method of Collecting Sleep Data	Gender	Average Daily Sleep in Hours (+s.d.)
USS PROVIDENCE and other SSN or SSBN Blasingame (2001)	NA	167 submariners	Survey	NA	Self-report ~6 (while at sea) (NA)
USS PROVIDENCE, USS CONNECTICUT, and other SSN or SSBN Gamboa (2002)	NA	258 submariners	NA	NA	NA
USS STENNIS (CVN) Nguyen (2002)	Operation Enduring Freedom NAO (3 days)	33 enlisted Sailors	Actigraphy and sleep logs (n = 28)	22 males 6 females 5 NA	6.28 (NA)
USS STENNIS (CVN) Sawyer (2004)	Operation Enduring Freedom (7 days)	24 crewmembers	Profile of Mood States (POMS) administration Actigraphy and sleep logs (n = 29)	19 males 5 females	NA
USS HENRY M. JACKSON (Osborn, 2004)	At sea trials (32 days)	41 submariners	Actigraphy and sleep logs (n = 29)	Males	6.67 (+2.56)
HSV-2 SWIFT McCauley, Matsangas, and Miller (2004)	Transiting and conducting sea-keeping trials (13 days)	19 total; 1 officer 16 enlisted 2 civilians	Sleep logs (mainly) and actigraphy	18 males 1 female	7.5 (+2.13)
HSV-2 SWIFT Archibald (2005)	GOMEX 05-1 MIW (8 days)	21 total; 3 officers 18 enlisted	Actigraphy and sleep logs (n = 21)	19 males 2 females	6.78 (+1.5)
USS CHUNG HOON (DDG) Haynes (2007)	Predeployment training (14 days)	25 total; 2 officers 23 enlisted	Actigraphy (n=22) and sleep logs (n = 25)	NA	7.27 (+1.03)

USS LAKE ERIE and USS PORT ROYAL (CG) (Mason, 2009) and (N. L. Miller & Matsangas, 2009)	RIMPAC exercise 2008 (24 days)	70	Actigraphy and sleep logs (n = 70)	NA	5.58 (± 1.92)
USS RENTZ (Green, 2009)	Predeployment workups (24 days)	24 total, 3 officers 21 enlisted	Actigraphy and sleep logs (n = 24)	males	6.71 (NA)
Sleep on Motion- Based Platform (Grow & Sullivan, 2009)	Laboratory experiment (2 nights of sleep)	12 NPS graduate students	Actigraphy and sleep logs (n = 12)	11 males 1 female	NA

Table 2: NPS Sleep Studies in Training and Educational Environments

Unit or Program	Mission (Length of Study)	Participants	Method of Collecting Sleep Data	Gender	Average Daily Sleep in Hours (\pms.d.)
USN Enlisted training at RTC, Great Lakes Baldus (2002)	Enlisted training (~63 days)	31 USN recruits	Actigraphy and sleep logs (n = 31)	20 males 11 females	6.1(± 1.2)
USN Enlisted training at RTC, Great Lakes Andrews (2004)	Academic performance (3 years of test scores)	2,597 USN recruits	Test scores retrospective analysis; no sleep data	NA	NA
United States Military Academy, West Point, 4-Year Longitudinal Study of Sleep in Cadet (DeVany, 2007; Godfrey, 2006; Kenney & Neverosky, 2004; D. B. Miller, 2005; N. L. Miller & Shattuck, 2005; N. L. Miller, Shattuck, & Matsangas, Accepted for publication 2010b)	Military undergraduate university (4 years of data, 2 months per year)	~1,400 (80 cadets selected for actigraphic recording)	Actigraphy and sleep logs (n = 80) Surveys (n~1,400)	56 males 24 females	5.60 (+1.49)

USN Officer Candidate School, Newport, RI, (O'Connor & Patillo, 2003)	Officer training and indoctrination (6 days)	20 faculty and students	Actigraphy and sleep logs (n = 20)	NA	NA (NA)
MAWTS-1 (Maynard, 2008)	Flight training WTI 2-05 (43 days)	13 total, students (n = 6) instructors (n = 7)	Actigraphy and sleep logs (n = 13)	NA	Students: 5.62 Instructors: 6.10
	Flight training school WTI 1-06 (44 days)	20 students	Actigraphy and sleep logs (n = 20)	males	7.05 (± 0.74)
Fort Leonard Wood Miller et al. (2010)	Basic combat training (63 days per unit)	394 recruits and cadre	Actigraphy and sleep logs (n = 94 recruits)	59 males 35 females	Intervention: 5.89 (± 1.21) Control: 5.33 (± 1.18)

Table 3: NPS Sleep Studies in Combat and Operational Operations

Unit or Context	Mission (Length of Study)	Participants	Method of Collecting Sleep Data	Gender	Average Daily Sleep in Hours (\pm s.d.)
Warfighters in Iraq and Kuwait Dohoney (2004)	Operation Iraqi Freedom (OIF) Phase IV (NA)	273 total: 244 enlisted 22 officers	surveys	237 males 24 females 12 NA	Self-report 6.67 (NA)
USMC Rotary Wing Aviation Battalion in Iraq (N. L. Miller & Matsangas, 2006)	Rotary wing flight operations in Iraq (10 days)	20 pilots	actigraphy and sleep logs (n = 20)	NA	6.5 (± 1.66)
Naval Aviation MH-53 (Rotary Wing) squadron (Solberg, 2006)	Mine hunting operations (14 days)	25 aircrew	actigraphy and sleep logs (n = 25)	20 males 2 females 3 NA	7.47 (± 1.65)
Fort Benning Survey Miller et al. (2010)	Infantry officers returning from Iraq/Afghanistan (NA)	46 infantry officers	surveys	Males	Self report by OPTEMPO: Low: 7.8 (NA) Moderate: 6.0 (NA) High: 3.9 (NA)

NPS Studies in Fatigue in Naval Operations (from Table 1)

Studies on USN Submarines. This program of operational research began with two studies that examined self-reported sleep patterns of U.S. Navy submariners by Blassingame and Gamboa. In her thesis, Blassingame (2001) evaluated whether differences existed in the self-reported sleep of U.S. Navy submariners in four different operational environments: (1) at sea, (2) in port, (3) on shore duty, and (4) on leave. The analysis was based on survey data of U.S. Navy enlisted submariners (n = 143) with at least one year of experience on Fleet Ballistic Missile Submarine (SSBN) or on Fast Attack Submarine (SSN) platforms. Surveys were administered to Sailors assigned to either the USS PROVIDENCE (n = 93) or a convenience sample of submariners receiving care at the Naval Ambulatory Care Center (NACC), Groton, Connecticut (n = 74) who had served onboard SSBN or SSN platforms. Survey respondents were asked to indicate the number of hours they slept and the longest uninterrupted sleep they received in a typical 24-hour period for each of the four operational conditions. The results of the study (see Figure 3) showed that there are significant differences in the reported quality and quantity of sleep between the four operational conditions. Submariners reported getting less sleep (~6 hours per night) while “at sea” than in any of the other three conditions.

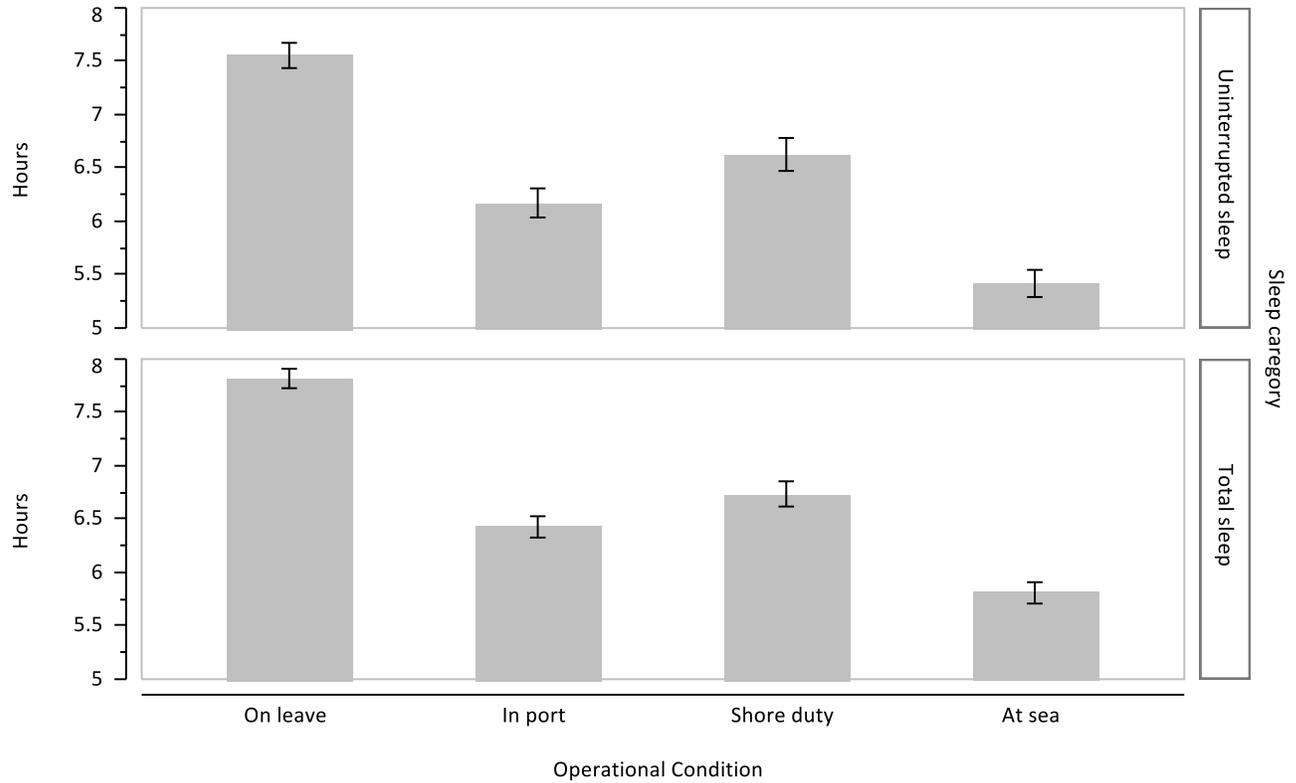


Figure 3: Daily sleep (“Total sleep”) and longest uninterrupted sleep episode per 24 hours (“Uninterrupted sleep”) (Blassingame, 2001).

In another survey of U.S. Navy submariners, Gamboa (2002) focused on environmental constraints and time in service as factors related to sleep and fatigue. His analysis was based on survey responses from 258 submariners, which combined the 143 respondents from Blassingame’s thesis with additional survey data obtained onboard the USS CONNECTICUT (SSN 22), a Seawolf-class attack submarine. The purpose of this research was twofold: (1) to determine whether the shift in working environment from shore duty to sea duty had an effect on enlisted submariner sleep patterns; and (2) to assess whether length of time in service was related to self-reported optimal sleep duration. As with Blassingame’s study, Gamboa verified that submariners reported shorter and more disrupted sleep patterns while underway. Rank, time in service, sea

time, and self-reported optimal sleep duration were also associated with the respondents' sleep patterns.

One of the more interesting findings of the Gamboa thesis was that more experienced submariners reported needing *fewer* hours of sleep at sea, compared to the amount they needed while on shore duty. It is as if the more experienced submariners knew that they were not going to be able to get adequate sleep while at sea, so they reported needing less sleep in this condition. One explanation for this finding could be that submariners who are more susceptible to sleep deprivation are more likely to drop out of the service or find other branches of military service more to their liking, and the remaining service members were a self-selected group that required less overall sleep to function. Another possible explanation offered was cognitive dissonance reduction theory, which holds that an individual will attempt to remedy a perceived dissonance or disconnect between two or more conflicting beliefs. According to Gamboa, these sleep-deprived submariners reported needing less sleep while at sea to reduce the perceived dissonance between the environment (that of continual sleep deprivation) and the knowledge that they need a certain amount of sleep to function optimally. While the individual's actual sleep requirement did not change between at-sea and in-port conditions, experienced submariners reported needing less sleep while at sea because they have learned that it will be impossible to get adequate sleep while at sea.

A third NPS study on U.S. Navy submariners was conducted by Osborn (2004) as part of a project sponsored by the Naval Submarine Medical Research Laboratory (NSMRL) at Groton, Connecticut. The purpose of the study was to evaluate the feasibility of a new watchstanding schedule that would be more in line with naturally

occurring circadian rhythms. The study was conducted between October 29 and December 2, 2003, onboard the USS HENRY M. JACKSON (SSBN 730 GOLD), a nuclear-powered, ballistic missile submarine. Data on 41 male volunteers (average age 25.6 years) were collected for 32 days and included exit surveys to elicit feedback from the crew and objective measures of sleep using wrist-worn activity monitors. Crewmembers were divided into three groups, each one following a different watchstanding schedule (two experimental groups, Schedules 1 and 2, and one control group, Schedule 3). The control group worked the 18-hour, three-section watch schedule currently in use in the U.S. submarine fleet (Stolgitis, 1969). The two experimental (alternative) schedules attempted to more closely simulate a 24-hour cycle (J. C. Miller, Dyche, Cardenas, & Carr, 2003). Results showed that the participants received, on average, 6.67 hours of daily sleep while underway. Analysis showed that Schedule 1 participants received the least amount of sleep. The participants on Schedule 2 received slightly more sleep, while Schedule 3 provided the most sleep in this study. The conclusion: the new schedules failed to provide a significant improvement in daily sleep.

The new schedule attempted to compress watch periods more closely together to extend opportunity for contiguous sleep. However, since little additional work was completed during the compressed watch periods, unfinished work was carried over into the period set aside for sleep, defeating the intention of the 24-hour schedule. Although laboratory studies had indicated otherwise, when tested in an operational environment, the new schedule was not better than the old 18-hour schedule due to the operational requirements on a submarine. The study did highlight the need for a watchstanding

schedule that allows for better sleep hygiene, along with more time to complete required work.

Studies on Surface Ships. Ongoing efforts in support of Operation Enduring Freedom (OEF) gave NPS researchers the opportunity to conduct a study on the effects of shiftwork and high operational tempo onboard the aircraft carrier USS JOHN C. STENNIS (CVN-74) (N. L. Miller & Nguyen, 2003; Nguyen, 2002). Before the data collection period, the aircraft carrier had shifted from day to night operations, with the entire crew working the night shift to support nighttime flight operations. Participants in the study were 28 enlisted crew members (22 males and 6 females). Sleep data were collected using wrist-worn activity monitors and sleep logs for 72 hours, while the carrier conducted routine combat operations. The study concluded that significant differences in the quality and quantity of sleep were determined by where the Sailors worked. A pattern of sleep deprivation was particularly evident in those individuals who were working topside and were exposed to bright morning sun immediately prior to bedtime. The results, displayed in Figure 4, show that individuals who worked belowdecks (and never saw daylight) received 7.35 hours of sleep, while those Sailors who worked topside averaged only 4.72 hours of sleep per day ($t = 6.19, p < 0.001$).

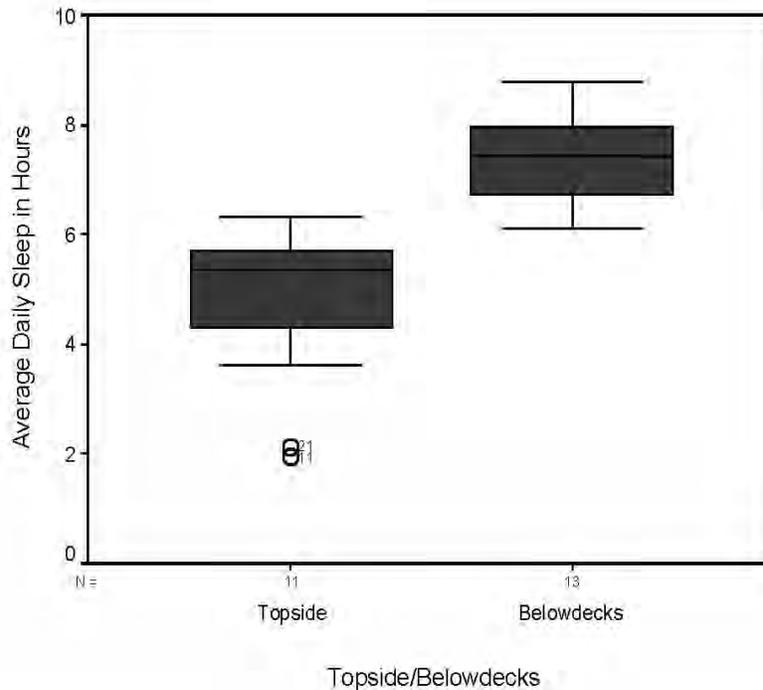


Figure 4. Average daily sleep in hours by working environment on the USS STENNIS.

A follow-on study by Sawyer (2004), also conducted aboard the USS STENNIS, examined the same participants in the Nguyen (2002) study. This study was a self-reported assessment of the mood state of Sailors who were required to abruptly change their work and rest habits. Mood states were assessed using the Profile of Mood States (POMS), a standardized, 65 five-point adjective rating scale that measures six affective states: Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment (McNair, Lorr, & Droppleman, 1992).

Mood states were monitored at three time points: when Sailors had been working the night shift for over 90 days, then 24 hours after shifting from working nights to working the day shift, and again one week following the shift to working during daylight hours. The results showed that younger participants were angrier than older participants

while on night shift work (Figure 5). This finding is particularly interesting considering the additional sleep required for adolescent and young adult populations and serves as a possible explanation for the differences observed.

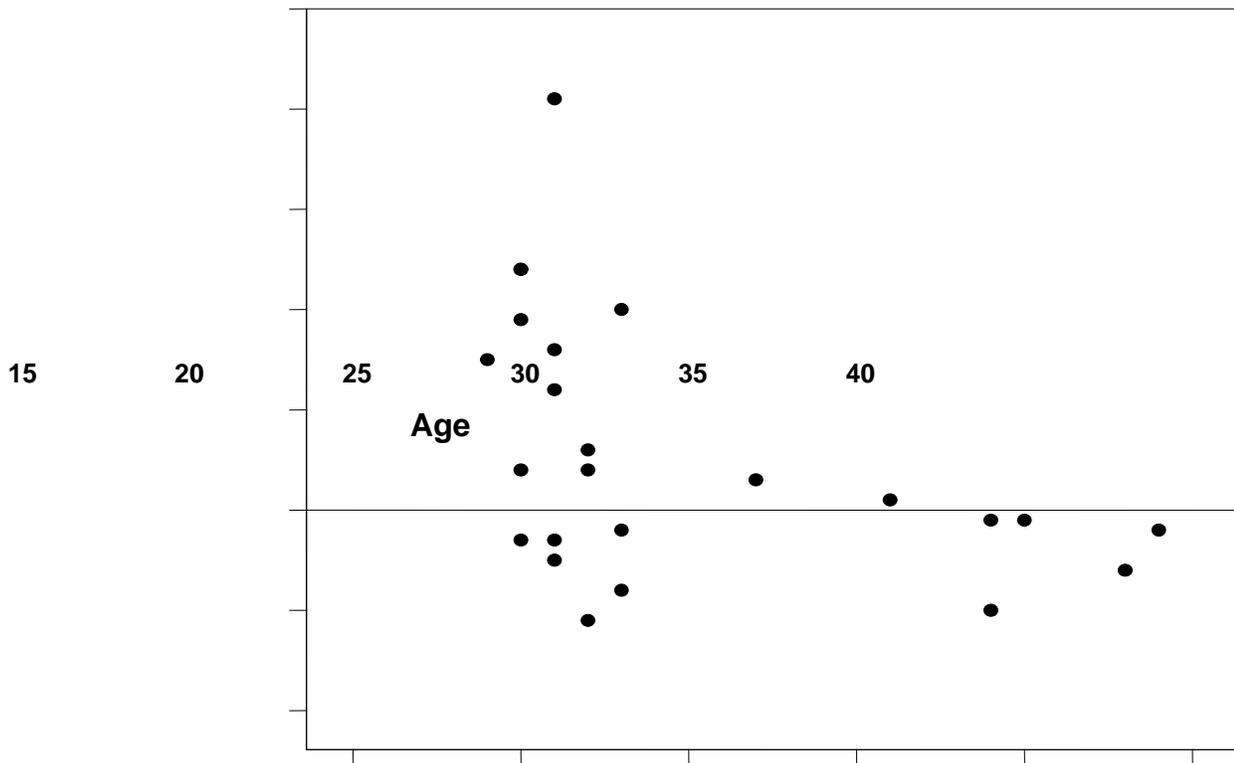


Figure 5. Anger - Hostility T scores versus age while working night shift (Time 1). T Scores above 50 indicate greater than normal anger-hostility.

There was also a significant interaction between mood state and sex, with female participants reporting significantly higher scores on Total Mood Disturbance (TMD) than the male participants. The scores for TMD of males dropped one week after shifting to daytime work indicating an improvement in overall mood; this pattern was reversed in females. This finding was statistically significant, although the sample size of the females was small ($n = 6$). These findings are seen in the Figure 6 which follows.

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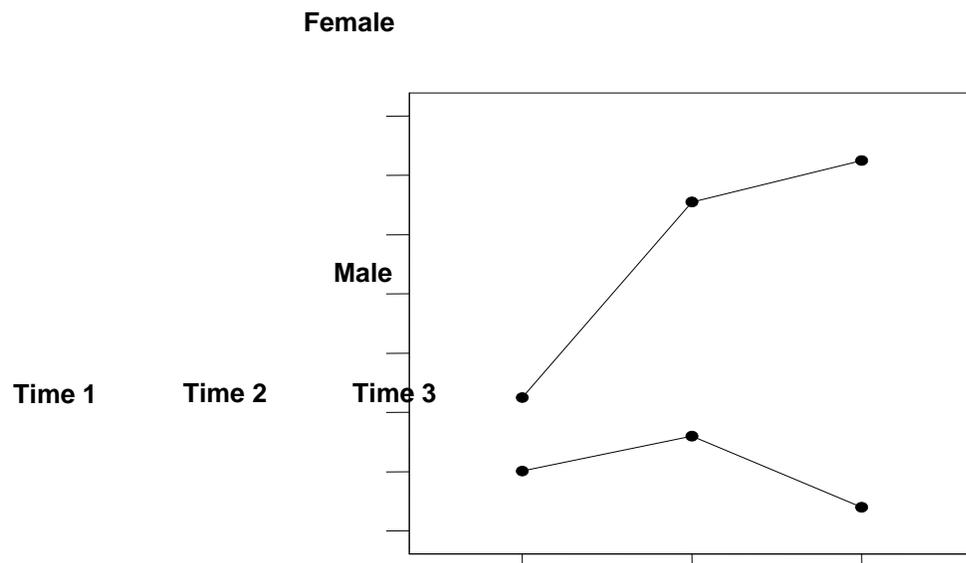


Figure 6. Total Mood Disturbance (TMD) scores, of participants working belowdecks, over time by gender.

In addition, participants working topside received significantly less sleep than those working belowdecks and their POMS scores reflected their fatigued state (Figure 7). The study provided vital information to the naval surface warfare community concerning the operational impact of mood states and performance caused by extended working hours, disruptive sleep, and reversal of sleep and work cycles.



Figure 7. Average daily sleep by work environment (sailors working topside versus those working belowdecks).

Studies on the High Speed Vessel, HSV-2. The next pair of NPS operational sleep projects was conducted on the “High Speed Vessel,” HSV-2 SWIFT, a 98-meter, wave-piercing catamaran. The main thrust of this research was to address the possible effects on personnel performance when sailors operate aboard high-speed vessels with nonconventional hull designs. The first study evaluated the effect of ship motion on sleep amount and quality, sleepiness, and predicted effectiveness (Matsangas & Miller, 2006; McCauley, Matsangas, & Miller, 2005). Data were collected during a 14-day transit while the ship travelled from Norway to Norfolk (10-23 May 2004) and executed sea-keeping trials (11-17 May 2004). Nineteen crewmembers participated in the study, during which sleep was assessed through actigraphy and activity logs. During the data collection period, the ship encountered sea states between 4 and 5. Wave heights were

significant, generally in the 8-10 foot range, average wave period was in the 8-12 second range, and the ship's speed varied from 10 to 36 knots, resulting in considerable motion for the sailors onboard. The motion states were quite severe at times, interfering with the wrist-worn activity monitors and resulting in an underestimation of the sleep received by the crew. Because of this complication, sleep amount and quality were determined from activity logs combined with bedtime start and stop times from the actigraphic recordings. This method of calculating sleep gave an overestimation of sleep, but given the severity of the ship's motion, it was the only solution deemed reasonable.

Whether assessed by self-report or by wrist activity monitors, it was evident that the sleep of crewmembers was interrupted by ship motion. This finding was echoed in the comments in the underway sleep logs, which indicated increased sleep fragmentation during the rough sea trials period (11-17 May). Thirty percent of the crew noted that sleep disruptions due to ship motion were common on the HSV-2 and identified ship motion as a significant cause of nighttime awakenings.

Building on the previous study on the HSV-2, Archibald (2005) examined the effects of noise, temperature, humidity, motion, and light on the sleep patterns of the crew of HSV-2 SWIFT during a Mine Interdiction Warfare (MIW) Gulf of Mexico Exercise (GOMEX) 05-1. The weather during GOMEX 05-1 was mild and the HSV-2 SWIFT was used as the command flagship, coordinating the movements of the other ships in the exercise. Consequently, the HSV-2 SWIFT was not required to operate at high speeds or maneuver quickly.

The study had 21 participants whose sleep patterns were collected using wrist-worn actigraphy and sleep logs. Results showed that the average daily sleep amount

was 6.78 hours, with the average sleep episode length being 5.40 hours. Time spent at sea, which is related to rank, was negatively correlated with sleep while underway ($r = -0.778$, $p = 0.001$), a finding consistent with that of Belenky (1997), who found that sleep amount is inversely proportional to rank with higher-ranking Soldiers receiving significantly less sleep than those junior to them.

Studies on the Navy Standard Work Week (NSWW). The most recent U.S. Navy operational studies were conducted on four surface combatants: the USS CHUNG HOON (Haynes, 2007), the USS LAKE ERIE and USS PORT ROYAL (Mason, 2009), and the USS RENTZ (Green, 2009). In an attempt to accurately calculate the number of Sailors required to man each class of ship, the United States Navy has developed a model called the Navy Standard Workweek. The Navy Standard Work Week (NSWW) represents a standardized version of one week of work performed by a single enlisted Sailor while at sea (Department of the Navy, 2007). After first determining the amount of work to be performed for operation of each class of ship, the NSWW is then used to calculate manning levels, which are a theoretical reflection of the minimum manpower resources necessary to accomplish the ship's mission. The workweeks for sea duty are based upon operational requirements under projected wartime conditions with units in Condition III steaming, as described in OPNAV Instruction 1000.16K, page C-1 (Department of the Navy, 2007):

The Navy's standard workweeks... are guidelines for sustained personnel utilization under projected wartime or peacetime conditions.... Daily workload intensity is a function of operational requirements; as such, the actual day-to-day management of personnel is the responsibility of the commanding officer. Under certain circumstances it may become necessary to exceed the standard workweek; however, extending working hours on a routine basis could adversely affect such matters as morale, retention, safety, etc., and as policy, such extensions should be avoided.

Using this NSW model, the 168 hours in one week for any given Sailor are divided into two categories: “Available Time” for duty (81.00 hours) and “Non-Available Time” (87 hours). Available Time is occupied by all required tasks that are performed by crewmembers; these include work or maintenance, watchstanding, training, and attending meetings. Non-Available Time is comprised of all personal time that is allotted to the crew, and includes messing, sleeping (56 hours on a weekly basis; on average, eight hours of sleep per day), and free time.

Three studies have addressed how well the NSW reflects the daily schedule of sailors: Haynes (2007), Mason (2009), and Green (2009). In his study to assess NSW issues, Haynes (2007) evaluated sleep patterns onboard the USS CHUNG HOON (DDG-93), an Arleigh Burke-class Aegis destroyer. Data were collected on 25 crewmembers during a 14-day period in February 2007. Data collected included actigraphy recordings (n = 22), and daily sleep and activity logs (n = 25). During the study period, the ship was conducting predeployment training while in Condition III. (Note: A ship’s deployment phase is preceded by a predeployment training cycle. During this phase, the crew conducts exercises involving warfare training and damage control at sea to simulate the operational tempo and conditions that might be experienced during battle.)

The results of this study are based on the information included in the sleep and activity logs. Analysis showed that participants reported 7.27 hours of daily sleep (stdev = 1.03 hours, median = 7.08 hours). Departmental analysis shows that participants in the Combat Systems Department reported 7.72 hours of daily sleep, whereas the Engineering Department reported 7.24 hours, and the least sleep was found among the operations personnel (6.15 hours of daily sleep). Crewmembers participating in the study worked

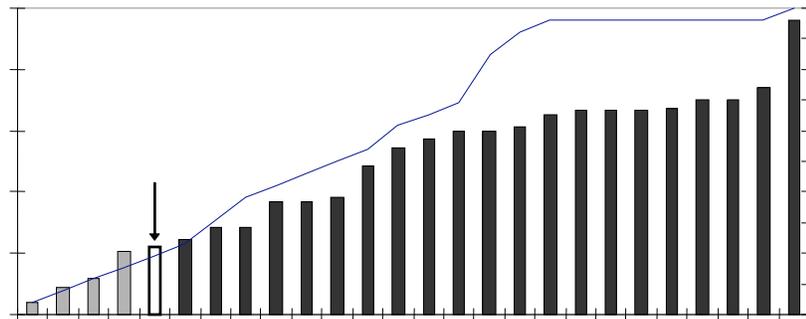
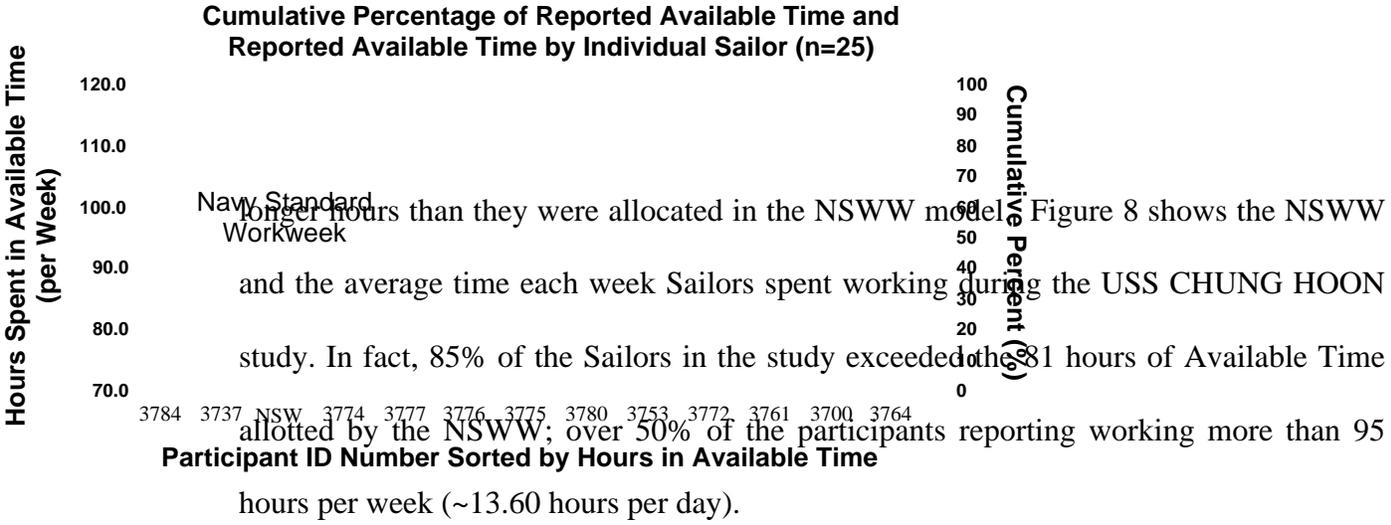


Figure 8. Hours spent working per week on the USS CHUNG HOON (Haynes, 2007).

On average, the Sailors worked 16.95 hours per week more than they were allotted in the NSW, which equaled 2.40 hours more per day in Available Time. The findings of this study led to a recommendation that revisions of the NSW be developed for enlisted Sailors based on departmental assignment, with a separate version of the NSW developed for officers. If implemented, this change would more accurately reflect the demands placed upon Sailors in the Navy and allow for calculation of more realistic manning of U.S. Navy vessels.

Another shipboard study of the NSW was conducted on the USS LAKE ERIE (CG-70) and the USS PORT ROYAL (CG-73), two Ticonderoga-class guided-missile cruisers (Mason, 2009). Like the study on the USS CHUNG HOON, the purpose of this

research was twofold: (1) to determine the amount of work and rest provided to Sailors during a typical training exercise, and (2) to determine if the NSWW accurately reflects the actual activities of Sailors onboard U.S. Navy cruisers.

Data were collected over an entire 24-day underway period (between July 7 and July 30, 2008) during the Rim of the Pacific Exercise (RIMPAC) Exercise 2008 (ship in readiness Condition III). Initially, the study included participants who wore wrist activity monitors (WAMs) and completed daily activity logs. The thesis reported on a total of 39 participants (6 officers and 33 enlisted personnel). The jobs performed by participants varied according to their rating, rank, and Navy Enlisted Classification Code (NEC) specialty. Ranks varied from E-1 through O-5. Additionally, the watch-stations manned by the Sailors included the Engineering, Combat Systems, Operations, Supply, and Administration Departments.

Results show that, on average, senior personnel, both officer and enlisted, slept approximately 2.00 hours less than allotted by the NSWW. Senior Chief Petty Officers and Chief Petty Officers (both enlisted-ranked E-8/7 participants) averaged 6.26 hours of sleep, while senior officers (Lieutenant Commanders [O-4] and above), averaged 6.38 hours of sleep per day. In contrast, junior personnel (enlisted ranks E-1 through E-3 and officer ranks W-2 through O-3) averaged 7.83 and 7.06 hours of sleep, respectively. Analysis indicated that 85% of the participants had more time on duty (“Available Time”) than allocated by the NSWW model throughout the entire underway period. In fact, only five participants worked less than the allotted 81.00 hours (and these individuals were not actively engaged in the RIMPAC exercise). The following figure depicts these findings.

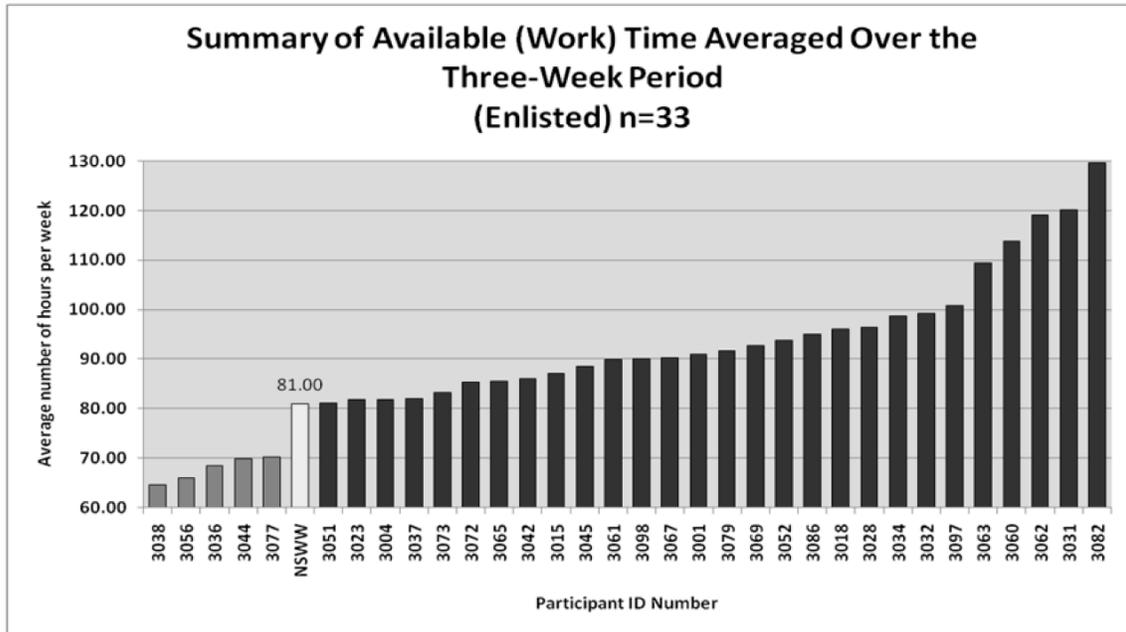


Figure 9. Weekly average available time (time spent working) for the 3-week underway period (Mason, 2009).

Departmental analysis showed that sailors in the Combat Systems Department worked the most hours: 15.00 hours more per week than the “Available” 81.00 hours of NSWW. Figure 10 shows the NSWW and the departmental breakdown time Sailors spent sleeping in this study. The Operations Department logged, on average, five hours more sleep than allowed in the NSWW. Final analysis of the data log sheets and Actiwatch indicate that 84% of the participants (excluding officers) were categorized as falling below the NSWW sleep allotment, averaging just over 47.00 hours versus 56.00 hours of sleep per week. Finally, as noted by Mason (2009), both ships had similar findings in all categories of the NSWW model.

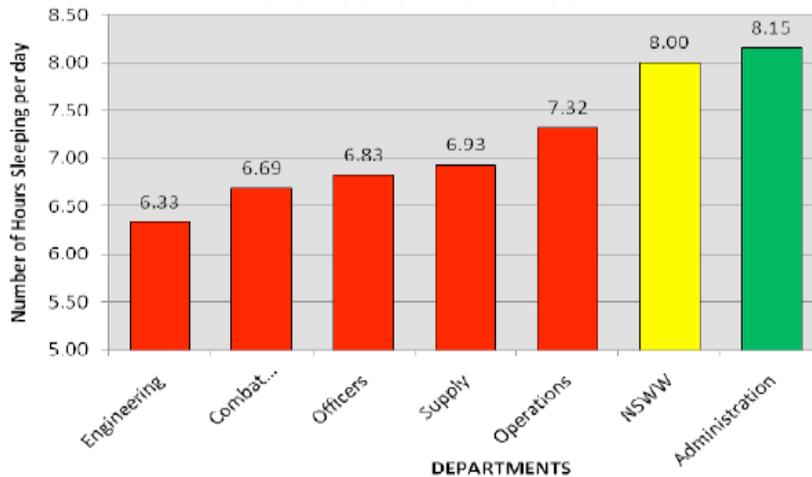


Figure 10. Average hours of sleep per night by ship's department (Mason, 2009).

The sleep data from sailors on these two ships were analyzed again to determine if the patterns of sleep were different between the two ships. This analysis focused on the sleep data of 70 participants—42 from the USS LAKE ERIE and 28 from the USS PORT ROYAL. Results showed that the average daily sleep obtained during the 3-week underway period was 5.58 hours (stdev = 1.92 hours, median = 5.51), with no significant differences between the two ships. For all Sailors on both ships combined, the length of the average sleep episode was 4.11 hours (s.d. = 2.12 hours, median = 4.05). However, the length of the average sleep episode differed between the two ships, with sleep episodes being shorter on the USS PORT ROYAL (USS LAKE ERIE: mean = 4.34, s.d. = 2.11, median = 4.32; USS PORT ROYAL: mean = 3.85, s.d. = 2.01, median = 3.72; $F(1,1822) = 26.6, p < 0.001, \text{Cohen's } d = 0.2378$). Sleep fragmentation was especially evident for Sailors on the USS PORT ROYAL, who averaged 1.36 sleep episodes per day, which was 11.6% more than seen in Sailors on the USS LAKE ERIE. This finding illustrates that napping was a strategy used by many crewmembers to alleviate their sleep debt. Since Sailors on the USS PORT ROYAL had less contiguous sleep, the sleep they

did receive was of less benefit than that received by their shipmates on the USS LAKE ERIE. Both crews suffered from significant sleep deprivation, as seen in Figure 11.

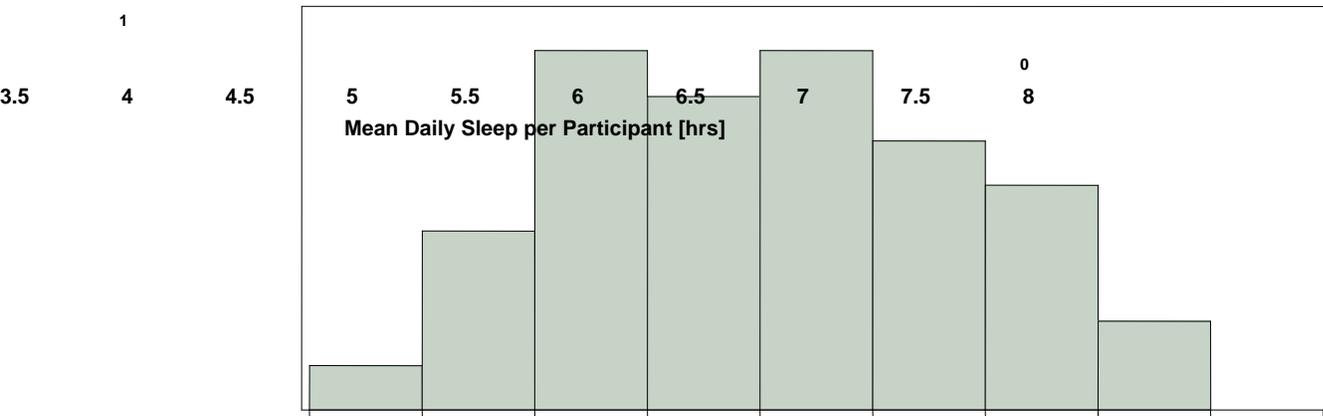


Figure 11. Average daily sleep per sailor on the USS LAKE ERIE and the USS PORT ROYAL over the entire 3-week data collection period (the number of participants is shown at the top of each bar).

The most recent NPS study on the NSWV examined work and rest patterns of Sailors on the USS RENTZ (FFG-46), an Oliver Hazard Perry-class guided missile frigate (Green, 2009). In her thesis research, Green examined the sleep of 24 Sailors during predeployment underway training periods. Her analysis yielded no surprises; just as in the previous two studies, sailors worked more hours than allocated in the NSWV and the participants were chronically sleep-deprived.

Studies of Fatigue on the Effectiveness of Training and Education (from Table 2.)

Studies of Fatigue and Training Effectiveness in USN Enlisted Recruits. United States Navy recruits are trained at the Recruit Training Command (RTC) in Great Lakes, Illinois. Basic training, or Boot Camp, lasts approximately 63 days, during

which the recruits are taught basic military knowledge and practice skills that prepare them to serve in the United States Navy. Recruits are under a closely controlled daily schedule and prior to December 2001, received only six hours of sleep per night. In December 2001, a decision was made to change the amount of sleep allowed by Navy recruits from six to seven hours of sleep per night (i.e., mandatory bedtime was from 2100 to 0400). In early 2002, the sleep regimen was changed once more to give recruits eight hours of sleep per night, sleeping from 2100 to 0500. In May 2002, the Navy recruit sleep regimen was finalized at eight hours per night, with bedtime at 2200 and wakeup at 0600. This last modification was selected to coincide with the recognized sleep requirements and naturally-occurring circadian rhythms of adolescents and young adults.

Two studies of Navy recruits at RTC were conducted by NPS to assess the impact of these decisions. The first study (Baldus, 2002) assessed the quantity and quality of sleep received by a sample of recruits in two 8-hour sleep conditions: 2100 to 0500 and 2200 to 0600. The data represent a cohort of recruits whose bedtimes shifted from 2100 to 2200 while they were attending Boot Camp. Sleep data and activity were evaluated using wrist-worn activity monitors (see Figure 12) and paper and pencil-based activity logs. Data were collected from April to June 2002 and comprised one complete cycle of recruit training. Participants included 31 recruits (20 males and 11 females), from five different recruit divisions.



Figure 12. Wrist-worn activity monitors on U.S. Navy recruits (Baldus, 2002).

Based on the recruits' sleep patterns, sleep was defined as nondisrupted (an 8-hour contiguous nighttime interval) or disrupted (any night having at least a 30-minute period of wakefulness after sleep onset or more than 45 minutes of wakefulness from bedtime until sleep onset). Standing watch, personal activities such as bathroom visits, or some other activity typically caused these disruptions in nighttime sleep.

Results from this study showed that although recruits were allotted eight hours of sleep per night, the overall average sleep for all recruits in this study was 6.10 hours (s.d. = 1.20 hours) per night (Baldus, 2002). Recruits tended to receive more sleep when following the 2200 to 0600 sleep regimen than when following the 2100 to 0500 sleep regimen. On average, the 2200 bedtime resulted in 22 more minutes of sleep per night per recruit—a finding that mirrored the shift in adolescent and young adult circadian rhythms that favors later bedtimes.

Finally, the study addressed the sex effect in sleep patterns. Although not statistically significant ($p = 0.20$), the results suggest a difference in sleep patterns between males and females. Over the course of the study, female recruits received an average of ten more minutes of sleep per night than did their male counterparts (6.24 hours versus 6.08 hours, respectively; see Figure 13). This difference was consistent whether looking at sleep amount in disrupted nights (females = 5.52 hours, males = 5.22 hours) or nondisrupted nights (females = 7.24 hours, males = 7.07 hours). Based on the findings of the study, it was concluded that the change in bedtime from 2100 to 2200 was beneficial and should remain in place.

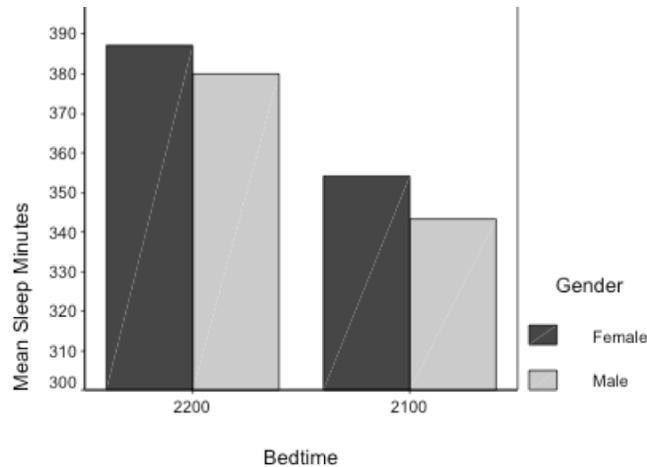


Figure 13. Minutes of sleep received by males and females at two different bedtimes (2100 and 2200). All recruits were allowed 8 hours of sleep (Baldus, 2003).

After this first descriptive study of sleep patterns of recruits, another study was conducted specifically to examine the academic performance associated with the two sleep regimens, i.e., six versus eight hours of nightly sleep (Andrews, 2004). One year of data with the 8-hour sleep regimen (calendar year 2003) was compared to two separate years when only six hours of sleep per night was allowed (calendar years 2000 and 2001). Average test scores by division and month were compared across the three years under investigation and included test scores of 2,597 recruits. Standardized test scores for each recruit and the year they were trained were entered into a regression model, adjusting for Armed Services Vocational Aptitude Battery (ASVAB) score and month of administration. Month of test administration and ASVAB scores were included in the regression equation in an attempt to adjust for seasonal variation and differences in individual recruit aptitude following the two different sleep policies. Results displayed in the Figure 14 show that recruits who received 6 hours of sleep per night scored significantly lower than the recruits who received 8 hours of sleep per night ($F(2, 33) = 29.97, p < 0.0001$).

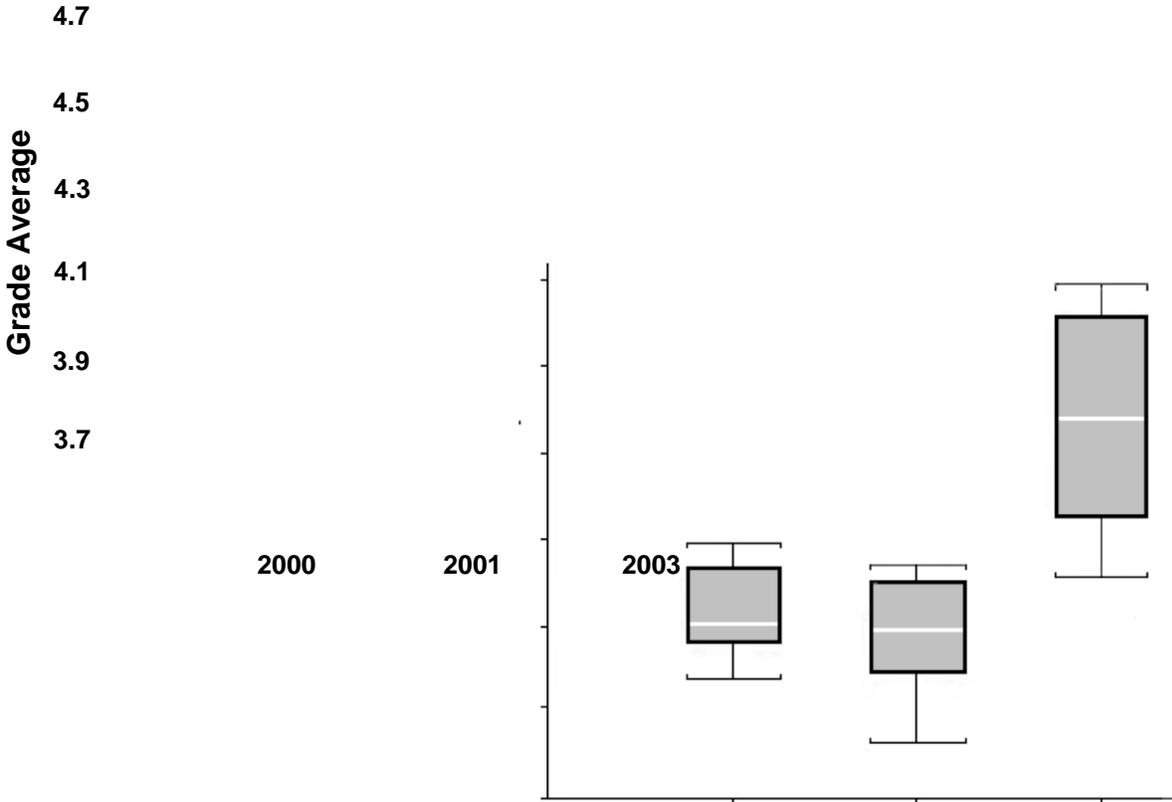


Figure 14. Standardized U.S. Navy grades for recruits receiving six hours of sleep per night (years 2000 and 2001) versus recruits receiving eight hours of sleep per night (Andrews, 2004). The blank line in the shaded box represented the median.

In short, recruits who received eight hours of sleep per night scored, on average, 11% higher (mean = 4.38, s.d. = 0.25, median = 4.38) than their counterparts who received only six hours of sleep (mean = 3.91, s.d. = 0.11, median = 3.9), supporting the hypothesis that more sleep was associated with significantly better academic performance. The findings were statistically significant and support the changes made by the Recruit Training Command. It should be noted that other administrative and procedural changes that occurred during this same time period (e.g., waterless hand washing before meals and sleeping in new barracks) may have contributed to the improvements in the test scores in 2003.

A Study of Fatigue and Training Effectiveness in U.S. Army Enlisted Recruits. Another study of training effectiveness in military recruits was conducted in late summer and fall of 2009 at Fort Leonard Wood, Missouri in U.S. Army

Basic Combat Training (BCT). This study is described in detail in Chapter 6 of an NPS dissertation by Tvaryanas (2010), but is briefly summarized here. The study set out to compare the training effectiveness of Army basic combat trainees in two training regimens. One company of trainees (n = 185) used a conventional training regimen, which allowed eight hours of sleep each night from 2030 to 0430, while another company of trainees (n = 209) used an experimental training regimen that allowed eight hours of sleep each night from 2300 to 0700. The primary question was whether sleep and recruit performance, including marksmanship, would be improved by adjusting the timing of the primary sleep period to be more in alignment with the naturally occurring patterns of sleep in adolescent and young adults.

Demographic and psychophysiological measures were collected at the start of the study using standard survey instruments and methods. A random sample of 95 recruits wore wrist activity monitors to record sleep quantity and quality throughout the study period. Weekly assessments of subjective fatigue and mood were collected using the POMS. Results of the actigraphic analysis showed that a 2.50-hour, phase-delayed sleep schedule improved sleep relative to the conventional BCT schedule, resulting in, on average, more than 30 minutes of extra sleep per night. Besides schedule, personal factors such as age and gender also influenced recruits' average total daily sleep: female recruits and recruits who were younger tended to sleep more. The schedule modification was shown to be effective in improving sleep over the entire course of BCT. Moreover, increased nightly sleep during the week in which marksmanship skills were trained (i.e., one week prior to the actual marksmanship tests) resulted in greater improvements in marksmanship.

This finding is in line with other studies that show higher skill acquisition following adequate amounts of sleep. The study demonstrated that schedule modifications that improve sleep are expected to result in improved marksmanship performance during BCT. Perhaps most importantly, such benefits may be obtained at no additional costs, since the content and length of training remains the same and there are no requirements for additional investments in new technologies or facilities.

A Study of Sleep in Undergraduate Military Education. In yet another study of sleep in military members, conducted at the United States Military Academy (USMA) at West Point, New York, the sleep patterns of nearly 1,400 military cadets (the USMA Class of 2007) were followed for four years during undergraduate education. The results of this study have been described in detail in two publications (N. L. Miller & Shattuck, 2005; N. L. Miller et al., Accepted for publication 2010b) but are summarized here. Academic performance, class ranking, attrition, race, sex, and morningness-eveningness preferences were recorded for the entire class. A sample of the class (n = 80) wore wrist activity monitors and completed activity logs for one month in the fall and spring academic semesters for the 4-year period.

As seen in Figure 15, on average, over the 4-year period, cadets slept less than 5.50 hours on school nights. Cadets napped extensively, perhaps in an attempt to compensate for chronic sleep debt. They slept more during fall than spring semesters. Male and female cadet sleep patterns vary dramatically, with males consistently receiving, on average, over 20 minutes less sleep than females.

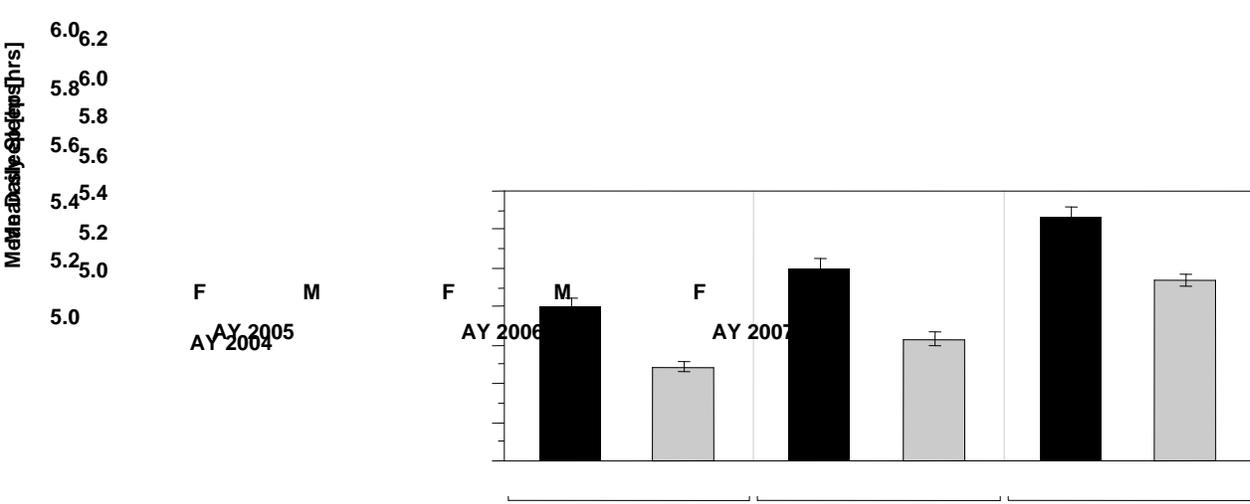


Figure 15. Average daily sleep in hours for females and males for academic years (AY) 2005, 2006, and 2007.

The study demonstrated that cadet sleep at USMA is related to academic year, semester, season, sex, day category (school day or weekend), and day of the week. For example, Figure 16 shows the pattern of sleep by academic year. Nightly sleep (sleep only in the major nighttime period) is shown by the dotted line. Daily sleep (i.e., total sleep in a 24-hour period, including naps) is indicated by the solid black line. With an increase in naps during the final year at USMA, daily sleep reaches a peak in the last year, continuing to rise over the 4-year period.

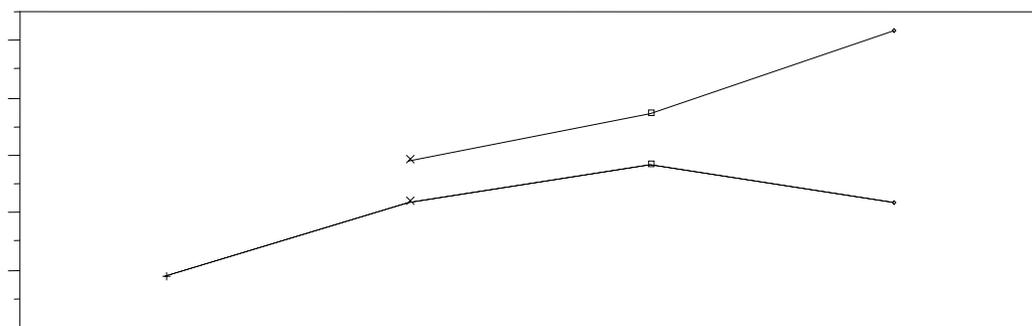


Figure 16. Average daily (solid black line) and night sleep (dotted line) achieved over each of four academic years at USMA.

The study showed that military cadets at USMA experience a severe and chronic sleep debt that may have long-term consequences. In addition to developing poor sleep hygiene habits, cadets may have difficulty in taking full advantage of the world-class education and training afforded them at West Point.

Studies of Fatigue in Combat and Operational Environments (from Table 3.)

Studies of Sleep and Compliance with Sleep Plans in Combat in Southwest Asia. This study assessed the impact of sleep logistics during Phase IV operations of Operation Iraqi Freedom (Doheney, 2004). Survey data were collected from warfighters operating in Iraq and Kuwait from August 25 to October 15, 2003, using a convenience sample of respondents. The study focused on answers to a 96-question survey designed to capture sleep patterns and determine adherence to sleep/rest plans. The survey asked questions relating to unit-level sleep/rest planning, sleep/wake patterns, warfighter fatigue and sleep latency, symptoms of sleep deprivation, and confounding lifestyle factors that impede sleep and rest. The respondent population included 273 participants (237 males and 24 females; average age = 29.80 years, s.d. = 8.96 years; average time deployed = 178 days, s.d. = 68.3 days).

Survey results showed that sleep deprivation was a significant problem for forces deployed to the Southwest Area region, especially those troops operating in Iraq compared to troops operating in Kuwait. In the survey, symptoms of sleep deprivation included difficulty concentrating, difficulty staying awake, difficulty waking up or getting out of bed when you are supposed to, still feeling very tired 30 minutes after waking up, experiencing noticeable mood changes, or difficulty falling asleep or staying

asleep. Based on the self-reported survey results, between 73% and 83% of the respondents indicate having moderate symptoms of sleep deprivation, whereas between 14% and 23% report having significant symptoms of sleep deprivation. These findings may be linked with the finding that only 38% of the sample reported that they were briefed on a sleep plan. Considering that the majority of the respondents included warfighters with ranks that have the responsibility to supervise the implementation of a sleep/rest plan, this suggested that units may not have considered the importance of implementing sleep/rest. Respondents reported getting 6.67 hours of sleep per day, most of which was on a cot, and napping occurred approximately every other day for around 45 minutes. Finally, 34% reported falling asleep at least once when they were supposed to be awake.

Another observation was that the units with effective sleep/rest plans had a higher probability of maintaining satisfactory performance effectiveness levels than those with no or ineffective sleep/rest plans. Further, units located in Kuwait had a higher probability of maintaining satisfactory performance effectiveness levels than units in Iraq, which supported the decision to rotate units out of Iraq and into Kuwait for rest and recovery. The data did not suggest, however, that there were differences in the probabilities associated with maintaining satisfactory performance effectiveness levels when other factors were considered (gender, MOS categories, or rank).

The data suggest that the respondents' sleep patterns did not support effective mission accomplishment. Based on the finding that only between 45% and 57% of the sample's sleep/wake patterns satisfactorily supported mission accomplishment, the author

concluded that typical standards of operational readiness, requiring 75% of the population to be mission capable, were not met.

Studies of Sleep in Helicopter Pilots in Iraq. This study, conducted in Iraq from May 21 to June 1, 2006, assessed sleep quantity and shifting sleep schedules during actual combat flight operations. Participants included 20 active duty pilots from a Marine Corps operational aviation battalion conducting flight operations in Iraq. Ten days of sleep data were collected through actigraphy and sleep logs. The study data included 210 sleep episodes, with durations ranging from 0.62 to 13.65 actual hours of sleep. Depending on sleep duration and the number of major sleep episodes in the course of each day, sleep incidents were categorized as either “sleep” or “nap.” In total, 16 naps were reported by 8 participants over the 10-day period. All naps occurred during days where the major sleep episodes took place at night. The average sleep duration per “sleep” episode was 6.37 hours ($n = 192$, $StDev = 1.65$ hours), while average “nap” length was 1.55 hours ($n = 16$, $StDev = 1.07$ hours). On average, participants in the study received approximately 6.50 hours ($stdev = 1.66$ hours) of total daily (24-hour) sleep. Participant sleep amount varied greatly within the unit, with the average daily (24-hour) sleep ranging from 5.00 to 7.90 hours (median 6.7 hours), with only 25% of the pilots receiving between 7 and 8 hours of daily sleep.

In order to assess the effect of sleep schedules on the amount of sleep obtained, participants were grouped according to their sleep schedule. Half of the participants ($n=10$) had a fixed sleep schedule, sleeping either during the daytime or at night. The other half of the participants’ sleep shifted at some time in the data collection period. Those participants with fixed schedules who slept only during daytime received their

sleep between 08:00 a.m. and 04:00 p.m. A second group, night sleepers with fixed schedules, slept between 11:00 p.m. and 07:00 a.m. Results showed that shift schedules were important predictors of the amount of sleep obtained. Participants with fixed sleep schedules received more sleep than participants whose sleep schedules changed ($F(1,189) = 3.91, p = 0.049$). In addition, sleep at night was better than sleep during the daytime. The following table shows these findings.

Table 4: Daily sleep vs. sleep schedule

Sleep Schedule	Number of Participants	Daily Sleep Mean (hrs)	Daily Sleep StDev (hrs)
Shifting from morning to night sleep	4	6.16	2.01
Shifting from night to morning sleep	6	6.43	1.76
Fixed schedule with daytime sleep only	4	6.53	0.59
Fixed schedule with night sleep only	6	6.79	1.78

The study results showed that 75% of the participants received a daily sleep amount significantly less than physiologically acceptable (Horne, 1985, 1988; Van Dongen, Rogers, & Dinges, 2003). Furthermore, a continuously accumulating sleep debt was evident in a large proportion of the participants. Sleep deprivation in this population was exacerbated by the fact that during the data collection period, there were no days that could be considered “weekends” or days off in which catch-up sleep could occur. Therefore, unlike civilians, these combatants did not have the opportunity to ameliorate their sleep deprivation during days off (Akerstedt & Torsvall, 1978; Dahlgren, 1981).

Studies of Reported Sleep Patterns in Army Commanders at Fort Benning, Georgia. This study addressed sleep deprivation issues during military operations from the viewpoint of Army officers newly returned from combat (N. L. Miller, Shattuck, & Matsangas, Accepted for publication 2010a). Forty-nine US Army Officers with recent combat experience were surveyed to assess their units' sleep patterns and to determine the tactics, techniques, and procedures used to counter the effects of sleep deprivation in their units. Results showed that despite Army policy, which requires units to develop and implement sleep management plans (Department of the Army, 2009), nearly 80% of the participants reported they had not been briefed on a sleep management plan during their most recent deployment. Over half of the respondents reported that fatigue was a problem in their units. During high operational tempo (OPTEMPO), which occupied nearly half of their time in combat, participants report receiving only four hours of sleep daily. Finally, the vast majority of respondents (82.6%) reported feeling sleep-deprived at least occasionally while at high OPTEMPO.

Conclusions and Future Directions

This chapter summarizes ten years of sleep research conducted by the Naval Postgraduate School in military settings. A common thread runs through all of these studies: US soldiers, sailors, and marines worldwide are accumulating a staggering sleep debt. Despite the US Navy's efforts to implement a Navy Standard Work Week, it is clear that its sailors continue to be sleep deprived—perhaps at an ever-increasing rate. Efforts to promote sleep hygiene in the US military ground forces have not been successful as documented by a widespread failure to comply with mandatory sleep

management plans. Continuing pressure to ‘downsize’ the military forces by reducing manpower has left the same amount of work to be done by an ever-shrinking work force.

Given that US warfighters suffer from chronic sleep deprivation, they will almost certainly experience deleterious effects on performance. The most egregious example of the consequences of chronic and acute sleep debt is when combat troops fall asleep when they need to be vigilant. While less obvious, other effects of chronic and acute sleep debt such as microsleeps, lapses in attention, memory and judgment, alterations in mood, and degraded decision-making also have far-reaching consequences for combat effectiveness. Military leaders would never send troops into harm’s way without the safety afforded them by armor and other personal protective equipment; yet sending troops on missions when they are sleep deprived is equally as dangerous to themselves and to others in their organization. That said, more research is needed to determine how sleep can be optimized on land, sea, or in the air. Accommodation of adolescent sleep needs has proven successful in various military training environments (e.g., USN Recruit Training Command at Great Lakes, US Army Basic Combat Training at FT Leonard Wood and United States Military Academy at West Point). Other military environments need to be examined to determine if the mitigating strategies used in training environments will be effective in operational environments.

Another prevalent and troublesome finding in this ten-year research effort is that senior military personnel report that they do not need more sleep. The inference is that the military has ‘weeded out’ individuals with normal sleep requirements by selecting and promoting those individuals who are less susceptible to sleep deprivation. Is attrition higher for individuals who require more sleep than those individuals who either need less

sleep or are less susceptible to sleep deprivation or shift work? Does an individual's sleep propensity constitute such an important demographic for the US military that this issue should be considered in the military selection process? More importantly, what does this selection process mean for those individuals who do elect to continue in service and what are the long-term sequelae of chronic sleep deprivation?

In conclusion, ten years of Naval Postgraduate School investigation of sleep in military settings has revealed that when military leaders are bold enough to employ innovative methods to enhance the quality and quantity of sleep, the result is improved effectiveness in training and performance. We conclude this chapter with the sober words of Jonathan Shay (1988): "Pretending to be superhuman is very dangerous. In a well-led military, the self-maintenance of the commander, the interests of his or her country, and the good of the troops are incommensurable only when the enemy succeeds in making them so. It is time to critically reexamine our love affair with stoic self-denial...If an adversary can turn our commanders into sleepwalking zombies, from a moral point of view the adversary has done nothing fundamentally different than destroying supplies of food, water, or ammunition. Such could be the outcome, despite our best efforts to counter it. But we must stop doing it to ourselves and handing the enemy a dangerous and unearned advantage."

References

- Akerstedt, T., & Torsvall, T. (1978). Experimental changes in shift schedules - their effects on well being. *Ergonomics*, *21*, 849-856.
- Anch, A. M., Browman, C. P., Mitler, M., & Walsh, J. K. (1988). *Sleep: A Scientific Perspective*. Englewood Cliffs, NJ: Prentice-Hall, Inc.
- Andrews, C. H. (2004). *The relationship between sleep regimen and performance in United States Navy recruits*. Monterey, California: Naval Postgraduate School.
- Archibald, K. (2005). *Effects of noise, temperature, humidity, motion and light on the sleep patterns of the crew of the HSV-2 SWIFT*. Monterey, CA: Naval Postgraduate School.
- Baldus, B. R. (2002). *Sleep patterns in U.S. Navy recruits: An assessment of the impact of changing sleep regimens*. Monterey, CA: Naval Postgraduate School.
- Belenky, G. L. (1997). Sleep, sleep deprivation, and human performance in continuous operations. Retrieved November 2, 2006, from <http://www.usafa.af.mil/jscope/JSCOPE97/Belenky97/Belenky97.htm>
- Blassingame, S. R. (2001). *Analysis of self-reported sleep patterns in a sample of US Navy submariners using non-parametric statistics*. Monterey, California: Naval Postgraduate School.
- Broughton, R. J., & Ogilvie, R. D. (1992). *Sleep, arousal, and performance*. Boston: Birkhauser.
- Carskadon, M. A. (2002). Factors influencing sleep patterns in adolescents. In M. A. Carskadon (Ed.), *Adolescent sleep patterns: Biological, social, and psychological influences* (pp. 4-26). Cambridge, UK: Cambridge University Press.
- Carskadon, M. A., Wolfson, A. R., Tzischinsky, O., & Acebo, C. (1995). Early school schedules modify adolescent sleepiness. *Sleep Research*, *24*, 92.
- Coren, S. (1997). *Sleep thieves: an eye-opening exploration into the science and mysteries of sleep* (1st ed.). New York: Simon & Schuster Inc.
- Dahlgren, K. (1981). Adjustment of circadian rhythms and EEG sleep functions to day and night sleep among permanent night workers and rotating shift workers. *Psychophysiology*, *18*, 381-391.
- Department of the Army. (2009). *Combat and operational stress control - Manual for leaders and soldiers* (Field Manual No. 6-22.5). Washington, DC.
- Department of the Navy. (2007). *Navy total force manpower policies procedures* (OPNAVIST No. 1000.16K). Washington D.C.
- DeVany, C. (2007, May 22-26). *Morningness / Eveningness preferences and performance*. Paper presented at the Second International Summer School on Mind, Brain and Education Basic and applied topics in biological rhythms and learning, Ettore Majorana Center for Scientific Culture, Erice, Italy.
- Dinges, D. F., & Kribbs, N. B. (1991). Performing while sleepy: Effects of Experimentally-Induced Sleepiness. In T. H. Monk (Ed.), *Sleep, Sleepiness and Performance*. Chichester, New York: Wiley.
- Dinges, D. F., Pack, F., Williams, K., Gillen, K. A., Powell, J. W., Ott, G. E., et al. (1997). Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. *Sleep*, *20*(4), 267-277.

- Dohoney, S. W. (2004). *Sleep logistics as a force multiplier: An analysis of reported fatigue factors from Southwest Asia Warfighters*. Monterey, California: Naval Postgraduate School.
- Gamboa, D. S. (2002). *An analysis of the effects of environment and career longevity on the sleep patterns of enlisted U.S. Navy submariners.*, Monterey, California: Naval Postgraduate School.
- Godfrey, A. G. (2006). *Optimizing daytime short sleep episodes to maximize performance in a stressful environment*. Monterey, California: Naval Postgraduate School.
- Green, K. Y. (2009). *A comparative analysis between the Navy standard workweek and the actual work/ rest patterns of sailors aboard U.S. Navy frigates*. Monterey, California: Naval Postgraduate School.
- Grow, B. J., & Sullivan, M. C. (2009). *Assessing the effect of shipboard motion and sleep surface on sleep effectiveness*. Unpublished Master of Science in Human Systems Integration, Monterey, CA: Naval Postgraduate School.
- Haynes, L. E. (2007). *A comparison between the Navy standard workweek and the actual work and rest patterns of U.S. Navy sailors*. Monterey, CA: Naval Postgraduate School.
- Horne, J. A. (1985). Sleep function, with particular reference to sleep deprivation. *Ann. Clin. Res.*, 17, 199-208.
- Horne, J. A. (1988). *Why we sleep*. Oxford: Oxford University Press.
- Kenney, A., & Neverosky, D. T. (2004). *Quantifying sleep and performance of West Point Cadets: A baseline study*. Monterey, California: Naval Postgraduate School.
- Kryger, M. H., Roth, T., & Dement, W. C. (Eds.). (2000). *Principles and practices of sleep medicine* (3rd ed.). Philadelphia: W.B. Saunders Company.
- Lindbergh, C. A. (1953). *Spirit of St. Louis*. New York: Scribners.
- Mason, D. R. (2009). *A comparative analysis between the Navy standard workweek and the work/ rest patterns of Sailors aboard U.S. Navy cruisers*. Monterey, CA: Naval Postgraduate School.
- Matsangas, P., & Miller, N. L. (2006). The effects of ship motion on the sleeping patterns of crewmembers aboard a high speed Naval vessel. [Meeting Abstract]. *Sleep*, 29(Suppl. S), A126-A126.
- Maynard, P. (2008). *Marine Aviation Weapons and Tactics Squadron One (MAWTS-1): sleep, fatigue, and aviator performance study*. Monterey, California: Naval Postgraduate School.
- McCauley, M. E., Matsangas, P., & Miller, N. L. (2005). *Motion and fatigue study in high speed vessel operations: Phase I report*. Monterey, CA: Naval Postgraduate School.
- McNair, D. M., Lorr, M., & Droppleman, L. F. (1992). *Profile of mood states manual*. San Diego, California: EdITS/EDUCATIONAL AND INDUSTRIAL TESTING SERVICE.
- Miller, D. B. (2005). *Sleep and predicted cognitive performance of new cadets during cadet basic training and the United States Military Academy*. Monterey, California: Naval Postgraduate School.

- Miller, J. C., Dyche, J., Cardenas, R., & Carr, W. (2003). *Effects of Three Watchstanding Schedules on Submariner Physiology, Performance, and Mood* (Technical Report No. 1226). Groton, Connecticut: Naval Submarine Medical Research Laboratory.
- Miller, N. L., & Matsangas, P. (2006). Effect of shiftworking on sleep attributes in operational environment: a case-study of a rotary wing squadron. Unpublished Manuscript. Naval Postgraduate School.
- Miller, N. L., & Matsangas, P. (2009). USS LAKE ERIE and USS PORT ROYAL sleep data analysis. Unpublished Data Analysis. Naval Postgraduate School.
- Miller, N. L., Matsangas, P., & Shattuck, L. G. (2008). Fatigue and its effect on performance in military environments. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (1st ed., pp. 231-250). Burlington, VT, USA: Ashgate Publishing
- Miller, N. L., & Nguyen, J. L. (2003). *Working the nightshift on the USS John C. Stennis: Implications for enhancing warfighter effectiveness*. Paper presented at the Human Systems Integration Symposium (HSIS) 2003: Enhancing Human Performance in Naval & Joint Environments, Vienna, VA.
- Miller, N. L., & Shattuck, L. G. (2005). Sleep Patterns of Young Men and Women Enrolled at the United States Military Academy: Results from Year One of a Four Year Longitudinal Study. *Sleep*, 28(7), 837-841.
- Miller, N. L., Shattuck, L. G., & Matsangas, P. (Accepted for publication 2010a). Sleep and Fatigue Issues in Continuous Operations: A Survey of U.S. Army Officers. *Behavioral Sleep Medicine*.
- Miller, N. L., Shattuck, L. G., & Matsangas, P. (Accepted for publication 2010b). Sleep patterns of college students: Longitudinal study of United States Military Academy cadets. *Sleep*.
- Nguyen, J. L. (2002). *The effects of reversing sleep-wake cycles on sleep and fatigue on the crew of USS JOHN C. STENNIS*. Monterey, California: Naval Postgraduate School.
- O'Connor, M. J., & Patillo, P. L. (2003). *Reengineering human performance and fatigue research through use of physiological monitoring devices, web-based and mobile device data collection methods, and integrated data storage techniques*. Monterey, California: Naval Postgraduate School.
- Osborn, C. M. (2004). *An analysis of the effectiveness of a new watchstanding schedule for U.S. submarines*. Monterey, CA: Naval Postgraduate School.
- Sawyer, T. L. (2004). *The effects of reversing sleep-wake cycles on mood states, sleep, and fatigue on the crew of the USS JOHN C. STENNIS*. Monterey, California: Naval Postgraduate School.
- Shay, J. (1998). Ethical standing for commander self-care: The need for sleep. *Parameters*, 28(2), 93-105.
- Solberg, B. J. (2006). *Sleep patterns of naval aviation personnel conducting mine hunting operations*. Monterey, CA: Naval Postgraduate School.
- Stolgitis, W. C. (1969). *The Effects of Sleep Loss and Demanding Work/Rest Cycles: An Analysis of the Traditional Navy Watch System and a Proposed Alternative*. Monterey, California: Naval Postgraduate School.
- Tvryananas, A. P. (2010). *A Discourse on Human Systems Integration*. Monterey, CA: Naval Postgraduate School.

- Van Dongen, H. P. A., & Dinges, D. F. (2000). Circadian rhythms and fatigue alertness and performance. In M. H. Kryger, W. Dement & T. Roth (Eds.), *Principles and practice of sleep medicine* (4th ed.). Toronto: W.B. Saunders.
- Van Dongen, H. P. A., Rogers, N. L., & Dinges, D. F. (2003). Sleep debt: Theoretical and empirical issues. *Sleep and Biological Rhythms*(1), 5-13.
- Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. *Child Development*, 69(4), 875-887.
- Wolfson, A. R., & Carskadon, M. A. (2003). Understanding adolescents' sleep patterns and school performance: A critical appraisal. *Sleep Medicine Reviews*, 7(6), 491-506.