UNDER SECRETARY OF DEFENSE
4000 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-4000

PERSONNEL AND READINESS

FEB 2 6 2021

The Honorable Adam Smith
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

The enclosed report is in response to section 749 of the National Defense Authorization Act for Fiscal Year 2020 (Public Law 116–92), which requires a study on the effects of sleep deprivation on the readiness of members of the Armed Forces and a report on the study's results.

This report summarizes the Department's findings following a comprehensive review of the impact of sleep deprivation on members of the Armed Forces, and an assessment of potential relationships between sleep deprivation and various medical and mental health conditions.

Thank you for your continued strong support for the health and well-being of our Service members, veterans, and their families. I am sending a similar letter to the Committee on Armed Services of the Senate.

Sincerely,

//SIGNED//

Virginia S. Penrod
Acting

Enclosure:
As stated

cc:
The Honorable Mike D. Rogers
Ranking Member

UNDER SECRETARY OF DEFENSE
4000 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-4000

PERSONNEL AND READINESS

FEB 2 6 2021

The Honorable Jack Reed
Chairman
Committee on Armed Services
United States Senate
Washington, DC 20510

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Sincerely,

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Virginia S. Penrod
Acting

Enclosure:
As stated

cc:
The Honorable James M. Inhofe
Ranking Member

Report to Congressional Armed Services Committees

Study on Effects of Sleep Deprivation on Readiness of Members of the Armed Forces

March 2021

In Response To: Section 749 of the National Defense Authorization Act for Fiscal Year 2020 (Public Law 116–92)

The estimated cost of this report or study for the Department of Defense (DoD) is approximately $109,000.00. This includes $100.00 in expenses and $109,000.00 in DoD labor.

Generated on 2020SEP03

RefID: F-8D0CEE4

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EXECUTIVE SUMMARY

Background

This report is in response to Section 749 of the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2020 (Public Law 116–92), which requires the Secretary of Defense (SecDef) to conduct a study of the effects of sleep deprivation on the readiness of members of the Armed Forces and submit a report on the study results. Study requirements include: 1) a standardized definition of sleep deprivation; 2) an assessment of the prevalence of sleep deprivation on members of the Armed Forces related to circadian rhythm disturbances from crossing multiple time zones, mission related maladaptive sleep practices, uncomfortable or otherwise inhospitable sleeping environments, and the use of stimulants and hypnotics to support operational tempo; 3) an assessment of whether there may be a relationship between sleep deprivation and medical conditions such as traumatic brain injury (TBI), post-traumatic stress disorder (PTSD), and depression; and 4) recommendations on efforts to mitigate sleep deprivation, pursuant to study findings.

Findings

Definition: Following a comprehensive literature review, for purposes of this study, the Department identified an empirically-derived definition of sleep deprivation germane to the examination of sleep deprivation on readiness and health promotion to inform the Department's prioritization of policy pertaining to sleep in the military context: ***Inadequate sleep that negatively impacts a Service member's military effectiveness, evidenced by 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***.

Prevalence of Sleep Deprivation: Amongst active duty personnel, inadequate sleep appears to be more the rule than the exception. In general, rates of individuals sleeping less than seven hours per night in the military are roughly twice of those in the civilian population. The prevalence of sleep deprivation varies across the Military Services and occupations. Several mission-related factors contribute to inadequate sleep in Service members, including austere deployment and training environments, cross-time-zone travel and its impact on circadian rhythm, operational and occupational requirements such as operations tempo, and inhospitable sleep environments. Use of stimulants and hypnotics can mitigate operational impacts of sleep deprivation and promote sleep in inhospitable sleep environments, but such pharmaceutical interventions offer short-term solutions and are neither intended nor suitable for sustained implementation.

Relationship with Other Conditions: Sleep deprivation is a symptom of—and a contributing factor to—mental health disorders and physical diseases, conditions, and syndromes. The presence of externally caused sleep deprivation may contribute to the development of PTSD, depressive disorders, and risk for TBI, and may exacerbate symptom severity in established cases. On the other hand, sleep deprivation can also be a sign or symptom of an underlying medical condition, such as depression, a side effect from medication or substance such as caffeine, or an endocrine disorder. The role of sleep deprivation as a contributing factor may be particularly important in relation to TBI, principally caused by accidents in the military population and more likely to occur when an individual is sleep deprived. Sleep deprivation substantially increases accident risk, which, in turn, increases the risk of TBI.

Results of the comprehensive review of the impact of sleep deprivation on the readiness and health promotion of members of the Armed Forces are informing the Department's policy development.

INTRODUCTION

This report is in response to section 749 of the NDAA for FY 2020 (Public Law 116–92), which requires the SecDef to conduct a study on the effects of sleep deprivation on the readiness of members of the Armed Forces, and provide a report on the results of this study. Study requirements include: 1) a standardized definition of sleep deprivation; 2) an assessment of the prevalence of sleep deprivation on members of the Armed Forces related to circadian rhythm disturbances from crossing multiple time zones, mission related maladaptive sleep practices, uncomfortable or otherwise inhospitable sleeping environments, and the use of stimulants and hypnotics to support operational tempo; 3) an assessment of whether there may be a relationship between sleep deprivation and medical conditions such as TBI, PTSD, and depression; and 4) recommendations on efforts to mitigate sleep deprivation, pursuant to study findings. Findings from this study are informing Department of Defense (DoD) policy.

BACKGROUND

Twenty-first century combat operations demanded an institutional shift in how military leaders manage Service member health as a critical component of readiness and performance. Throughout the wars of the past two decades, the DoD has shown an increasing commitment to Service member mental and physical readiness. This commitment is evident in the collaborative partnership between commanders and medical professionals striving to maximize wellness behaviors among Service members in training, operational, and combat environments. Throughout the DoD, an emphasis on physical activity, nutrition, resilience, sleep, and fatigue management has worked to mitigate the potentially deleterious effects of maintaining an always-ready force.

Sleep may be the most important biological factor that determines Service member health and combat readiness.[1] U.S. military personnel across settings tend to self-report significantly higher rates of sleep deprivation than the general national population.[2] The majority of Service members report they receive less sleep than needed to perform their military duties well.[3] Rates of sleep deprivation typically are higher in training and deployed settings than in garrison.[4,5] Between 27 and 38 percent of Service members indicate that the length of the duty day and the overall pace of 24-hour-per-day military operations result in sleep deprivation due to restricted opportunity for sleep.[6,7]

Although it can be argued that intermittent, short-term sleep deprivation due to operational and training demands is an unavoidable cost that must be paid to ensure an always-ready force, it is likely that prolonged and chronic sleep deprivation has the opposite effect on the readiness of the U.S. Armed Forces.[8] Impairment from sleep deprivation can be equivalent to the effects of alcohol intoxication[9] and significantly increases the risk of physical injury.[10] A growing body of research, reviewed in this study, indicates that sleep deprivation has significant effects on the physical, cognitive, and emotional functioning needed for readiness, occupational, and operational mission fulfillment in the military.[11] Risk of accident in training, operational, and combat environments significantly increases if Service members are sleep deprived.[12] To counteract the effects of sleep deprivation, Service members consume large amounts of caffeine. There is some evidence that moderate doses of caffeine can maintain alertness, attention, and vigilance during short-term sleep deprivation.[13] However, caffeine countermeasures cannot replace the need for sleep, and overuse of this stimulant drug in military settings can disrupt sleep patterns and increase levels of sleep deprivation.[14,15] If sleep problems are not addressed, medical and psychological health conditions can be exacerbated, resulting in persistent symptoms. As sleep disruption is a core symptom of depression, PTSD, and TBI, individuals with these conditions show a greater risk for sleep-related problems following combat deployment.[16]

Military commanders can help prevent and mitigate the effects of sleep deprivation among their Service members.[17] Risk mitigation begins with a leader's commitment to duty schedules that allow for eight hours of sleep with adequate recovery time when mission requirements result in reduced or disrupted sleep.[18] Leaders can take specific steps to monitor caffeine intake and decrease environmental disruption in sleep areas.[19] Several well-established techniques exist for managing anticipated travel-related sleep disruptions, such as tactical naps and sleep banking.[20,21] Leaders can also encourage the use of behavioral interventions to improve sleep quantity and quality, such as the use of mobile applications to help track sleep.[22,23] If viewed as a key component of readiness, military cultural attitudes regarding sleep deprivation can be shifted to ensure that Service member performance is optimized, and even enhanced, rather than compromised.

METHOD

A comprehensive review was conducted of relevant scientific literature published in the past two decades to inform the identification of an empirically sound, standardized, 'consensus' definition of sleep deprivation; assess the prevalence of sleep deprivation among Service members; identify factors resulting in sleep deprivation in the military context; examine the use of stimulants and hypnotics in response to sleep disturbances caused by operational tempo; and support an examination of the relationship between sleep deprivation and medical conditions, such as TBI. Complete summaries of selected literature reviews are included as attachments and cited by topic within the body of this report.

FINDINGS

It is important to note at the outset that sleep deprivation is not a specific disease, and that most sleep-related disorders typically result in sleep deprivation. Two of the most common of these disorders often affect Service members. The first is insomnia. Insomnia diagnoses result from inadequate sleep quantity or quality due to problems initiating or maintaining sleep, which interferes with occupational functioning and occurs despite an adequate opportunity for sleep.[24] Whereas all individuals with insomnia typically experience partial sleep deprivation, not all individuals with partial sleep deprivation will meet diagnostic criteria for insomnia.[25] The second condition that typically results in sleep deprivation and is common among Service members is behaviorally-induced insufficient sleep syndrome (BIISS). Like insomnia, BIISS is characterized by inadequate sleep quantity or quality that interferes with occupational functioning. Unlike insomnia, BIISS is characterized by an inadequate amount of time spent in bed or a restricted opportunity to obtain adequate sleep. This could result from factors beyond the control of the individual (e.g., occupational demands such as long hours or shift work) or leisure activities (such as television or video games).[26,27] Studies of both insomnia and BIISS have been used in the research literature to capture the occurrence of sleep deprivation as defined herein.

Standardized Definition of Sleep Deprivation

A consensus of reports in the scientific literature defines sleep deprivation as "obtaining inadequate sleep to support adequate daytime alertness."[28] There are two general types of sleep deprivation: total sleep deprivation and partial sleep deprivation (See Attachment 1, *Sub Types of Sleep Deprivation*, for the complete literature review):

- Total sleep deprivation is defined as a period of continuous wakefulness that exceeds 24 hours, or getting zero sleep time during the typical sleep-wake cycle.[29,30] Total sleep deprivation is relatively rare for more than short periods of time and can be lethal after extended periods, but may occur in military settings due to operational demands such as sustained operations, overnight duty, extended missions, or direct combat.[31]

- Partial sleep deprivation (or sleep restriction) is defined broadly as at least one night of partial or interrupted sleep.[32] Although the amount of sleep needed each night varies by individual, partial sleep deprivation is operationalized typically as less than seven hours of sleep per night for adults.[33]

- Chronic partial sleep deprivation is partial sleep deprivation with at least one week in which an individual gets less than seven hours of sleep on most nights and is unable to get sufficient recovery sleep to make up for lost sleep time.

- The requirement for a minimum of seven hours of sleep per night aligns with recommendations from numerous scientific organizations, including the American Academy of Sleep Medicine, the Sleep Research Society, and the National Sleep Foundation.[34,35] Large-scale studies further support this cut point by showing that optimal performance in communication and reasoning require between seven to eight hours of sleep.[36,37] Chronic partial sleep deprivation (or chronic sleep restriction) occurs following at least one week of consecutive days with partial sleep deprivation (i.e., less than seven hours of sleep per day).[38]

Both total sleep deprivation and partial sleep deprivation can have significant effects on cognitive, emotional, and physical capabilities that directly affect military performance. These include deficits in marksmanship, physical training, decision making, and risk-taking behavior.[39,40,41,42] As applied to the military context, sleep deprivation is operationalized as meaning *inadequate sleep that negatively impacts a Service member's military effectiveness, evidenced by a reduced ability to execute complex cognitive tasks, communicate effectively, quickly make appropriate decisions, maintain vigilance, and/or sustain a level of alertness required to carry out assigned duties*.[43,44,45]

Prevalence of Sleep Deprivation

In the general U.S. population, approximately 28 to 37 percent of adults receive less than seven hours of sleep per night.[46,47,48] In comparison, U.S. military personnel across settings tend to self-report significantly higher rates of partial sleep deprivation than the general U.S. population. Results from the DoD Health Related Behavior Surveys conducted between 2005–2018 indicate that between 55 and 76 percent of Service members endorsed sleeping less than seven hours per night.[49,50,51,52] The most recent estimates indicate that 64 percent of Service members report less than seven hours of sleep per night.[53] Members of the Air Force consistently reported a higher rate of sufficient sleep (seven hours or more) per night when compared with the other Military Services.[54,55,56]

Circadian Rhythm Disturbances from Crossing Multiple Time Zones

Travel-related circadian rhythm disturbances (see Attachment 2, *Impact of Sleep Deprivation in Specific Military Contexts*, for a detailed literature review) in the military context primarily affect aviation Service members and units that must deploy on short notice across several time zones.[57] The majority of military studies on circadian rhythm disturbances related to travel focus on the use of medication to reduce the effects of crossing multiple time zones rapidly,[58] as reviewed under the subsequent section of this report, *Prevalence of Use of Stimulants and Hypnotics to Support Operations Tempo*.

For military operations that last longer than two weeks (such as a deployment of Service members involving several months), jet lag is worse upon arrival to the new time zone and dissipates over time. In general, an individual is able to adapt to a time zone change of one hour per day. For example, if an individual travels three time zones, it will take three days for that individual to adapt to the new time zone. Service members who engage in operational requirements (such as nighttime operations or rotating shifts) that prevent them from experiencing normal light-dark cycles may have exacerbated performance impairment due to circadian rhythm disturbance, which will prevent or delay adjustment to a new time zone.[59]

Mission-Related Maladaptive Sleep Practices

A number of specific military contextual factors affect the occurrence of sleep deprivation in operational environments. Examples of such factors include austere deployment and training settings with inhospitable sleeping environments, and circadian rhythm disturbances caused by rapidly crossing multiple time zones. Despite reporting high rates of sleep deprivation, only a minority of Service members indicate that sleep deprivation affects their overall job performance.[60] Army surveys from 2009 to 2013 showed that 27 to 34 percent of Soldiers reported concern about not getting enough sleep.[61] A DoD survey conducted in 2015 found that 56 percent of Service members reported getting less sleep than needed to perform their military duties well.[62]

Culturally and operationally, a Service member's ability to maintain maximum performance while being sleep deprived has been lauded as a key skill for military personnel and has been perceived to demonstrate toughness.[63,64] Among military commands, attitudes toward sleep may range from viewing sleep as a controlled ration to asserting that a need for sleep is a sign of weakness.[65] Leadership plays a significant role in whether Service members in a given unit experience partial sleep deprivation. Army surveys indicate that only 26 percent of leaders encourage Service members to get adequate sleep, while 24 percent work to ensure an adequate sleep environment, and 35 percent consider sleep as an important factor in operational planning, such as establishing an adequate shift rotation that supports sufficient sleep.[66]

Deployed Settings

Rates of partial sleep deprivation have been assessed in deployed settings. Among Army personnel in Afghanistan, 86 percent report sleeping less than seven hours per night.[67] Air Force personnel in Afghanistan report an average total sleep time of 6.7 hours per night, with 15 percent of personnel reporting less than 4.5 hours per night, and 74 percent rating sleep quality as significantly worse in the deployed environment.[68] A study of Navy personnel in Afghanistan similarly showed an average total sleep time of 5.9 hours per night, with 67 percent reporting less than seven hours per night.[69] These results are consistent with other studies of Army and Marine Corps personnel, which demonstrate that 50 percent of deployed Service members report sleeping five hours or less per night.[70] Leaders also experience partial sleep deprivation when deployed. Army infantry officers report that sleep in the deployed environment depends on operations tempo (OPTEMPO), with officers typically sleeping only four hours per night during high OPTEMPO.[71] Despite these high rates, a much smaller percentage (3.6 percent) of deployed Service members seeks behavioral health care for sleep-related concerns.[72] Partial sleep deprivation can also continue following deployment. The majority of Service members in the Millennium Cohort Study reported sleeping less than seven hours per night, regardless of deployment status.[73] Between 90 and 180 days after return from deployment, 72 percent of Service members reported sleeping less than seven hours per night.[74]

Training Settings

Military training settings show significant rates of partial sleep deprivation, despite evidence that trainees perform better when they receive more sleep.[75] Cadets at the United States Military Academy consistently sleep less than five hours per night during the week, and remain below seven hours per night on weekends, suggesting that they are unable to effectively recuperate from "sleep debt" (the cumulative effect of not having enough sleep).[76] Soldiers in basic training report receiving an average of five–six hours of sleep per night, and are typically awoken by interruptions between two–four times per night.[77] Similarly, Marines in training settings frequently report less than six hours of sleep per night on average, even when periods of sleep deprivation are not required for operational tasks.[78] National Guard members show a significant decrease in hours of sleep per night when comparing typical sleep patterns to sleep during training, with an average of six hours of sleep per night during training exercises.[79] Soldiers in Ranger School typically receive an average of only three hours of sleep per night, and engage in operational training that requires several days of total sleep deprivation.[80] Even when training schedules in basic training environments specify eight hours of sleep a night for trainees, the actual number of hours of sleep received by trainees—as measured by actigraphy (a non-invasive method of monitoring human rest and activity cycles)—is significantly less.[81] Although the belief exists that short-term sleep deprivation during training is necessary to prepare Service members for combat environments that might require conducting operations with little sleep, sustained chronic partial sleep deprivation may become counterproductive to overall training objectives.[82]

Occupational Duty Requirements and Maladaptive Sleep Practices

The majority of Service members experiencing circadian rhythm disruptions are likely to work in occupations that require regular or recurring shift work. Shift work causes circadian rhythm disturbance that contributes to sleep deprivation, if not properly managed. Extensively detailed in the literature (Attachment 2), occupational duty requirements may be the most prominent factor driving chronic partial or total sleep deprivation among Service members. Shift work (scheduled, unplanned, and ad-hoc), unpredictable schedules, 24-hour duty assignments, and manning shortages all can result in sleep deprivation among Service members.[83] In both deployed and garrison settings, military personnel face extended duty hours to accomplish all maintenance, training, and administrative duty requirements.[84] When deployed, between 15 and 21 percent of Soldiers report that high OPTEMPO results in sleep deprivation.[85] Thirty-six to 38 percent of Soldiers and 27 to 33 percent of Marines indicate that the length of the duty day provides insufficient time to complete personal business, in turn resulting in restricted opportunity to sleep.[86] Although sleep deprivation in the military has been compared to equivalent civilian occupational categories, military Service members (55–76 percent) report significantly greater rates of partial sleep deprivation than firefighters (46 percent), law enforcement officers (40 percent), and healthcare professionals (40 percent).[87]

Uncomfortable or Otherwise Inhospitable Sleeping Environments

Due to the nature of military operations in austere locations worldwide, a number of environmental factors in combat, training, and operational settings may contribute to sleep deprivation.[88] Between 27 and 35 percent of deployed Army personnel surveyed between 2010 and 2013 reported that a poor sleep environment affected their ability to get sufficient sleep.[89] Although Service members may be encouraged to "sleep whenever you can" in operational settings, it is unlikely that sleeping in tactical vehicles, military aircraft, large transient tents, hangars, or near machinery, is restorative.[90] The most common environmental factors reported by deployed Air Force personnel as affecting their sleep were loud noise outside sleeping tents, uncomfortable beds, loud noise inside sleeping tents, and uncomfortable heat or cold.[91] Ambient temperature is an important environmental factor that can contribute to partial sleep deprivation, as it influences the optimal core body temperature, which is an important factor in sleep initiation and maintenance.[92] When deployed to a warmer climate, it can take Service members several days for their regulation of core body temperature to normalize, in turn resulting in partial sleep deprivation.[93] Summer nighttime temperatures in Iraq and Afghanistan during Operation IRAQI FREEDOM and Operation ENDURING FREEDOM frequently exceeded ideal ranges for sleep initiation.[94,95] When daytime temperatures in the deployed environment exceed 90 degrees Fahrenheit (°F), most base construction projects occur at night; however, this causes significant noise that disrupts the sleep of Service members in tents.[96] Furthermore, daytime temperatures of most U.S. military basic training sites exceed 90°F for more than 50 days per year, potentially contributing to sleep deprivation among trainees.[97] Military trainees also report receiving insufficient bedding to stay warm during the night in barracks, contributing to partial sleep deprivation.[98]

Occupational factors also can interact with environmental factors to worsen sleep deprivation. Problems caused by shift work during 24-hour operations can be exacerbated by light and noise contamination, if crew sleeping areas are not set aside from daytime operation personnel, not adequately blacked out to ensure darkness, or are still used for mission-related tasks (such as obtaining keys or log books).[99] In initial entry settings, trainees report several factors that disrupt their sleep, such as excessive noise in communal sleeping areas, light contamination from security lights, and rotational nighttime duties that wake both the trainees and their bunkmates.[100] Furthermore, co-location of crew sleeping areas with work areas—such as flight crews sleeping near the airfield—tends to contribute to significant sleep disruption due to noise characteristic of 24-hour operational environments.[101] All these factors suggest that maintaining adequate sleep for personnel should be a primary consideration in establishing operational rotations, work locations, and standard operating procedures.

Prevalence of Use of Stimulants and Hypnotics to Support Operational Tempo

Throughout the past several decades, studies have examined a number of pharmacological interventions to determine their effectiveness for mitigating the effects of sleep deprivation in military operational settings. Attachment 3 provides a comprehensive review of the literature, *Pharmacological Intervention to Support Operational Tempo*. These studies include investigation of stimulants (such as caffeine and modafinil) and sedative-hypnotics.

Caffeine

The intent of controlled caffeine administration in military settings is to maintain operational performance at typical levels when Service members are sleep deprived.[102] The efficacy of caffeine and other psychostimulants is transient, and can delay—but not replace—the need for sleep.[103] Evidence synthesized from across military and civilian studies provides some support that moderate doses of caffeine ((approximately 200–300 milligrams (mg)) can maintain levels of alertness, attention, vigilance, and reasoning during sleep deprivation.[104,105] In addition, caffeine doses over 200mg show positive effects on physical performance, including time-trial or sprint speed, muscle strength and endurance, and time-to-exhaustion.[106]

Energy Drinks

Although coffee is the most prevalent source of daily caffeine among Service members overall, energy drinks are the most common source among younger Service members.[107] Energy drinks are considered dietary supplements, with caffeine content typically ranging from 80–300mg per serving.[108] Studies show significantly higher rates of energy drink consumption in the U.S. military compared to the general population. For example, a survey of military personnel in operational, training, and medical settings found that 53 percent of Service members consumed at least one energy drink in the past 30 days, while 38 percent consumed at least one energy drink per week.[109] Among Service members, U.S. Army personnel use energy drinks most frequently (54 percent), while U.S. Air Force personnel consume energy drinks least frequently (26 percent).[110] Although generally considered relatively benign, caffeine consumption can have unfavorable effects. Service members who regularly consume energy drinks frequently report problems sleeping; the alerting effects of caffeine possibly contribute to these problems, especially if caffeine consumption occurs within six hours prior to bedtime.[111] Energy drink consumption can bring significant health risks, including cardiac arrest, myocardial infarction, spontaneous coronary dissection, and coronary vasospasm.[112,113] In contrast to studies on carefully dosed caffeine during military tasks, energy drinks likely provide an irregular dose of caffeine at various intervals, possibly canceling out potential benefits and increasing operational risk. Furthermore, many energy drinks contain several substances (e.g., taurine, guarana, excessive amounts of B vitamins) in addition to caffeine, the effects of which, both individually and in combination, have yet to be fully determined.[114]

Modafinil and Dextroamphetamine

The prescription stimulant drug dextroamphetamine is approved for use under the direction of a flight surgeon in Army, Navy, Air Force, and Marine Corps aviation.[115,116,117,118] The prescription drug modafinil is also approved for wakefulness promotion under the direction of a flight surgeon in the Air Force, depending on specific Major Command guidance.[119] A recent study on the prevalence of these drugs in combat aviation operations showed that pilots used either dextroamphetamine or modafinil in 35 percent of combat sorties.[120] Research on these stimulants generally demonstrates that they are safe and effective in counteracting fatigue during combat or other emergency conditions, and can be used to their optimal effect upon following strict dosing and recovery sleep guidelines.[121] Studies on modafinil use have generally demonstrated effective restoration of normal performance levels for several hours during total sleep deprivation.[122,123,124,125] Outside of use for counteracting fatigue during combat or other emergency situations, these pharmaceutical measures should be used only after other options for ensuring adequate aircrew rest (especially protected sleep time) have been exhausted.[126]

Sedative-Hypnotics

Prescription sedative-hypnotic drug use has occurred in military contexts for many years. These drugs are most effective for short-term use to promote sleep in inhospitable military environments, to counteract circadian adjustment associated with jet lag, or to facilitate work shift transitions.[127] Approximately 11 percent of Service members report using prescribed sedative-hypnotics to facilitate sleep in deployed settings.[128] Studies on workplace and operational applications of short-term sedative-hypnotic drug use have shown some benefits, including alleviating sleep debt by restoring sleep levels to baseline prior to periods of known sleep deprivation, and possibly counteracting environmental noise effects.[129,130,131] Sedative-hypnotic drugs have been used frequently to treat partial sleep deprivation related to clinical sleep conditions. Between 2009 and 2015, approximately 2.4 million prescriptions for sedative-hypnotic medications were given to active duty Service members.[132] Table 1 details the number of prescriptions filled by active duty Service members for three different sleep-related, non-benzodiazepine sedative-hypnotics—zolpidem, zaleplon, and eszopiclone—in Military Health System (MHS) encounters from FY 2016–FY 2019. These data show that prescriptions for sleep-related non-benzodiazepine sedative-hypnotics have decreased overall between FY 2016 and FY 2019. Although there is continued use of sedative-hypnotics in the military, studies show that behavioral treatments are preferable to sedative-hypnotic drugs for ongoing treatment of insomnia, which is supported by the downward trend in the percent of Service members with a filled prescription during this period.[133] Clinical guidelines recommend only brief treatments with these sleep medications to help restore sleep to baseline; behavioral interventions are recommended for long-term treatment of insomnia.[134]

Table 1. Prescriptions for sleep-related sedative-hypnotics among active duty Service members				
VARIABLE	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**
New Prescriptions Filled	45,243	42,107	37,012	34,088
Refills	11,155	11,049	9,684	8,382
TOTAL PRESCRIPTIONS FILLED	56,398	53,156	46,696	42,470
Unique Patients	31,462	29,066	26,123	23,829
Prescriptions Filled per Patient	1.8	1.8	1.8	1.8
Percent of Active Duty Service Members with a Filled Prescription	2.06%	1.91%	1.70%	1.53%
ESTIMATED PREVALENCE*	3,692.4	3,500.9	3,046.1	2,718.9

*Reflects prescriptions filled per 100,000 Service members. Data retrieved from the MHS Management Analysis and Reporting Tool reflect prescriptions in the direct care system for zolpidem, zaleplon, and eszopiclone. Data also reflect all prescriptions for these medications, which may include off-label use for non-sleep-related symptoms.

Relationship between Sleep Deprivation and Medical Conditions such as Traumatic Brain Injury, Posttraumatic Stress Disorder, and Depression

Traumatic Brain Injury

As reviewed herein, sleep deprivation can result in significant physical and neuropsychological decrements—including deficits in arousal, attention, cognition, and performance—that contribute to risk for sustaining a TBI.[135,136] The majority of TBIs in the military are due to training accidents, accidental falls, and motor vehicle accidents.[137] A systematic review and meta-analysis found that workers with sleep problems had a 1.6 times higher risk of injury than workers not reporting sleep problems, and that overall, 13 percent of work injuries were related to sleep problems.[138] Data from the National Transportation Safety Board indicate that 40 percent of motor vehicle accidents are related to fatigue and insufficient sleep.[139] In the military, Service members with duty-related sleep deprivation are far more likely to experience a motor vehicle accident or work-related injury.[140]

Clinically, sleep problems are among the most common symptoms following a TBI, including insomnia, excessive daytime sleepiness, sleep fragmentation (repeated, short sleep interruptions), and changes in sleep architecture (pattern of sleep between sleep stages).[141] These factors, in turn, contribute to significant partial sleep deprivation.[142,143] In the military, estimates of sleep problems following a TBI range from 25–30 percent.[144] Repetitive TBIs also significantly exacerbate sleep deprivation, with one study showing that 50 percent of Service members with more than one incident of TBI reported subsequent partial sleep deprivation.[145] Sleep deprivation can exacerbate other symptoms of TBI, resulting in greater impairment and long-term sequelae.[146,147] Failure to address sleep problems and subsequent sleep deprivation following TBI can impede recovery and delay return to work, in turn contributing to the development of chronic maladaptive sleep behaviors. The Defense and Veterans Brain Injury Center clinical recommendations, as well as DoD and Department of Veterans Affairs guidelines indicate that standard sleep interventions should be implemented among Service members and veterans with a TBI, to include sleep assessment, sleep education, and an emphasis on non-pharmacologic interventions to address sleep problems.[148,149] These clinical recommendations and guidelines intend to standardize care for Service members with TBI and sleep disorders, and mitigate the impact of sleep disorders on TBI recovery.

Mental Health Conditions

Partial sleep deprivation is a common symptom and potential risk factor for many mental health conditions, particularly mood and anxiety disorders.[150,151] Compared to those without a diagnosis, recent combat veterans with a mental health diagnosis report significantly worse sleep quality, sleep quantity, sleep efficiency, and sleep latency, and more sleep disturbances.[152] Data from deployed Service members show a clear relationship between partial sleep deprivation and reported psychological health problems, with 23 percent of Service members screening positive for a mental health disorder when sleeping three or fewer hours per night, and 17 percent of Service members screening positive for a mental health disorder when sleeping four hours per night.[153] Overall, partial sleep deprivation shows significant deleterious effects on mood and emotional reactivity; difficulties with mood and emotional reactivity can be part of several mental health diagnoses.[154,155] Furthermore, a study of U.S. Army Soldiers found those with poorer subjective sleep quality over an extended period reported higher emotional exhaustion and feelings of role overload.[156] Specific symptoms such as anxiety may also be more intense and frequent among sleep-deprived individuals.[157] In addition to these overall relationships, sleep deprivation may complicate the general diagnostic and clinical course of several specific mental health conditions, including PTSD, depression, suicidal behavior, and TBI.

Posttraumatic Stress Disorder

Sleep deprivation—often through nightmares or insomnia—is a core symptom of PTSD and a factor than can exacerbate PTSD daytime symptomatology (e.g., hypervigilance, irritability).[158] Estimates suggest more than 90 percent of combat veterans with PTSD also experience significant chronic partial sleep deprivation.[159,160,161] Partial sleep deprivation prior to combat deployment significantly increases the risk of subsequent PTSD.[162,163] Similarly, sleep disruption due to nightmares prior to military deployment can increase the risk of PTSD symptom onset during the six months following deployment.[164] Partial sleep deprivation due to insomnia is the most common reported PTSD symptom among Service members returning from deployment.[165] Similar to other mental health conditions, individuals diagnosed with PTSD tend to have significant sleep disruption, including lighter sleep that results in being awakened more easily; less time in deep slow-wave sleep; and greater density of rapid eye movement sleep (suggesting greater overall partial sleep deprivation).[166,167] Compared to combat-deployed peers who do not develop PTSD, Service members and veterans diagnosed with PTSD report significantly greater partial sleep deprivation that results from a combination of lower total sleep time, worse sleep efficiency, and higher sleep latency.[168]

Several studies demonstrate that partial sleep deprivation can worsen the occurrence of daytime PTSD symptoms. Sleep deprivation at four months following return from deployment predicts the severity of PTSD symptoms at 12 months.[169] Partial sleep deprivation of less than six hours of sleep per night served as the strongest predictor of PTSD symptoms among Service members 90–180 days following deployment.[170] Service members and veterans with partial sleep deprivation of less than four hours per night are at greater risk of having persistent PTSD symptoms that extend over a seven to ten year period.[171] Furthermore, sleep-related symptoms partially account for the relationship between combat exposure and development of PTSD symptoms; this finding suggests that partial sleep deprivation should be addressed early among Service members at risk for PTSD.[172]

Depression

Overall estimates suggest that 60 to 84 percent of patients with depression report insomnia, with associated sleep deprivation as a primary symptom.[173] Across military and civilian population samples, partial sleep deprivation significantly increases risk of developing depression symptoms. [174,175,176,177] Risk of sleep deprivation as a secondary effect of insomnia also may continue after remission of depression symptoms.[178] Among Service members, partial sleep deprivation experienced prior to deployment increases the risk of developing depression symptoms following deployment.[179] Sleep deprivation may also be the primary factor that determines whether combat-exposed Service members develop depression symptoms, since sleep deprivation partially accounts for the relationship between combat exposure and depression symptoms.[180] Similarly, sleep deprivation may account for the link between TBI and depression symptoms among Service members.[181]

Sleep Deprivation and Suicide Risk

Several meta-analyses demonstrate a clear association between sleep disruptions—resulting in chronic partial sleep deprivation—and suicidal behavior.[182,183,184,185] This includes increased risk of suicidal ideation, suicide planning, suicide attempts, and death by suicide. The lowest risk of suicide is associated with eight hours of sleep per night, with an 11 percent increase in risk for each hour of sleep deprivation.[186] Within diagnostic groups at risk of suicide (such as depression and PTSD), sleep disruption and associated chronic partial sleep deprivation approximately double the risk of individuals to engage in suicidal behavior.[187,188]

Findings among military populations have been less clear. One study of U.S. military personnel showed an association between reported insomnia symptoms and suicidal ideation, when controlling for other mental health factors.[189] However, an analysis of three U.S. military sample populations receiving mental health care showed no association between severity of chronic partial sleep deprivation and suicidal ideation, when controlling for reports of depression symptoms.[190] In a study of suicide deaths among U.S. Veterans from Operation ENDURING FREEDOM and Operation IRAQI FREEDOM, Veterans reporting sleep problems in the previous year died by suicide significantly sooner (75 days) after their last contact with the Veterans Health Administration than did those who did not report sleep problems (174 days), even when controlling for other mental health factors.[191] These studies suggest that reporting of partial sleep deprivation may predict increased risk of suicide, but this relationship may depend on several additional risk factors, such as co-occurring mental health disorders.

Prevalence of Healthcare Encounters to Address Sleep Deprivation

Table 2 details the number of MHS encounters for three different categories coded by providers in medical records related to sleep deprivation: sleep deprivation, insufficient sleep syndrome, and insomnia. These data cover FY 2016–FY 2019. As shown in Table 2, the overall prevalence of sleep deprivation and insufficient sleep syndrome requiring medical care in the MHS is relatively low. Although excluded from the definition of sleep deprivation in this study, the prevalence of insomnia cases—the most common sleep-related condition diagnosed among Service members—is significantly higher and reflects about five to six percent of the overall Service member population.[192] Nonetheless, these rates of insomnia cases are significantly lower than reported rates of sleep deprivation from surveys of Service member sleep patterns.

A clinic-based study of active duty military members found that 68 percent of Service members referred for sleep evaluation reported sleeping less than seven hours per night.[193] Another study found that among a cohort of female Service members referred for formal sleep evaluations, sleep duration on workdays was significantly less than sleep duration on days off.[194] Given the relative frequency of insomnia cases as shown in Table 2, compared to diagnosed cases of sleep deprivation, it is likely that partial sleep deprivation in the military is due to lifestyle choices and occupational requirements.[195,196]

Table 2. Service members seeking medical care for sleep deprivation and related medical conditions

CONDITION	FY 2016	FY 2017	FY 2018	FY 2019
SLEEP DEPRIVATION				
Total Cases	2,267	1,863	2,374	2,350
Prevalence Estimate*	148.42	122.70	154.86	150.44
INSUFFICIENT SLEEP SYNDROME				
Total Cases	1,186	1,371	1,388	1,407
Prevalence Estimate*	77.65	90.30	90.54	90.07
INSOMNIA				
Total Cases	88,606	85,360	80,654	80,815
Prevalence Estimate*	5,801.01	5,621.92	5,261.32	5,173.66
ANY CONDITION RELATED TO SLEEP DEPRIVATION				
Total Cases	90,444	87,223	82,889	83,056
Prevalence Estimate*	5,921.34	5,744.62	5,407.11	5,317.13

*Cases per 100,000 Service members. Data retrieved from the MHS Management Analysis and Reporting Tool reflect medical transactions in both the purchased care and direct care systems across both inpatient and outpatient settings, wherein target diagnoses were recorded in any available diagnostic position.

Taken together, the findings above consistently show that Service members report significant rates of chronic partial sleep deprivation. Discrepancies between endorsed sleep deprivation, care seeking behavior, and reported job performance may show that certain groups of Service members lack insight into the unanticipated impact of sleep deprivation, particularly given the body of research reviewed herein that demonstrates its significant impact on functioning.

SUMMARY FINDINGS: SLEEP DEPRIVATION RISK MITIGATION STRATEGIES

Based on the results of this comprehensive review of the impact of sleep deprivation, the following identified areas reflect strategies to mitigate the risk of sleep deprivation and improve sleep among Service members:

- To the extent possible, in non-deployed and training units, duty schedules should afford Service members eight consecutive hours of sleep every 24 hours.

- Duty schedules requiring shift work should implement forward-rotation of changing shifts (day to evening to night), and utilize eight-hour shifts whenever possible.

- Operational and tactical battle plans should account for the impact of sleep deprivation, ensuring eight hours of sleep every 24 hours, with sufficient opportunities for sleep banking and recovery sleep when operational requirements result in less than eight hours of sleep every 24 hours.

- Establishment of an enlisted unit-level sleep trainer to promote the use of strategies to mitigate sleep deprivation throughout the unit and advise command on ensuring that Service members receive adequate opportunity for sleep.

- Provision of leader training in basic officer and non-commissioned officer military professional education courses on sleep leadership and the impact of sleep deprivation on physical performance.

- Provision of pre-deployment training for Service members and leaders on developing an environment conducive to sufficient sleep.

- Provision of health promotion guidance and an educational campaign for Service members on caffeine consumption limits to include identifying products with excessive caffeine content.

- Use of well-established strategies for managing travel-related circadian rhythm disturbance such as those developed by elite athletes.

- Expansion of adoption and training of brief behavioral interventions to address sleep problems in primary and specialty care.

- Promotion of government-developed mobile application use for sleep management, including ensuring Service members have an opportunity to download these mobile applications onto personal mobile devices prior to completion of basic training.

- Establishment of a clearinghouse repository for sleep resources to ensure dissemination and availability to front-line military leadership.

The sections below outline the basis for the above identified risk mitigation strategies.

Commitment to a Duty Schedule that Allows Eight Hours of Sleep

Due to the sustained high OPTEMPO during the past two decades, daily duty requirements have taken priority over Service members obtaining enough sleep to perform these duties at optimal levels. The research reviewed herein clearly demonstrates that the majority of Service members are experiencing partial sleep deprivation, regardless of current duty status (e.g., deployed, in garrison, in training).[197,198,199] Of all factors reviewed in this report that contribute to sleep deprivation, the most prominent is the need to afford Service members an adequate opportunity for sleep, in response to operational requirements for unplanned and ad-hoc shift work, unpredictable schedules, 24-hour duty assignments, manning shortages, and extended duty hours.[200,201] Greatly increasing leadership commitment to promote and encourage Service members to obtain adequate sleep, and directing command involvement to ensure an adequate sleep environment, are vital tools to mitigate operational and readiness risks—both physical and mental—associated with sleep deprivation.[202]

As the first step toward reducing and mitigating the impact of sleep deprivation in the military, commanders at all levels should commit to sleep leadership through duty schedules that allow Service members to get eight hours of sleep per night.[203] This would include a specific requirement to plan eight hours of sleep for every 24-hour period into training and battle plans, with planned recovery time of two to three consistent nights of sleep, if operational requirements take precedence for any period of seven or more days.[204,205] In the operational environment, units required to engage in significant sleep deprivation should be placed "off cycle" for at least three nights to ensure recovery to baseline performance. Pilot studies with brigade combat teams have shown that limiting the duty day to eight hours, while adapting schedules to account for family obligations, significantly improved work quality, physical fitness scores, and number of hours sleep per night without negatively impacting unit mission.[206] In this way, transformational leadership—through proactive strategies that set a good example and promote collective effort—can mitigate some of the effects of sleep deprivation on work performance in military settings.[207] Sleep leadership should be emphasized as a core competency in readiness, and consideration given to evaluating leaders based on whether the Service members in their stewardship are receiving a sufficient number of sleep hours per night.[208]

Commanders who must operate 24-hour duty cycles should leverage existing research on shift scheduling.[209] Eight-hour shifts that synchronize with the 24-hour clock have the least impact on performance and highest satisfaction among Service members.[210] Forward shift rotation (day to evening to night) has been well established as preferable for both performance and sleep cycles.[211] Longer intervals between shift rotations generally promote better sleep and allow for less circadian disruption.[212] Furthermore, crew briefings, meals, and other mandatory tasks should account for sleep cycles to avoid interrupting Service member sleep.[213]

As part of mission planning, military researchers recommend the establishment of specific unit-level sleep plans for use during training and sustainment operations.[214] Researchers furthermore recommend the establishment of a "sleep trainer" at the unit level to facilitate sleep plans, monitor individual sleep performance, and train unit members on behavioral strategies for minimizing and mitigating sleep deprivation.[215]

Environmental Considerations

Military leaders and commanders should consider several specific environmental factors when planning where Service members will sleep in training and operational settings.[216] An optimal sleep environment should include complete darkness, good ventilation, ambient temperatures ranging between 17 degrees Celsius (°C) and 28°C at 40–60 percent relative humidity, and noise levels below 35 decibels (dB).[217,218] Air conditioning for barracks and operational settings is crucial for ensuring that sleep environments remain within optimal levels.[219] Non-invasive monitoring of sleep areas should be conducted regularly for factors such as decibel levels from machinery, temperature, and light contamination.[220] Service members should be provided with supplies such as eye masks and earplugs to counteract suboptimal sleep settings.[221]

Tactical Naps and Sleep Banking

When periods of total sleep deprivation are required due to operational necessity, planning specific periods of sleep before or during sustained operations may be of benefit equal to caffeine.[222,223] Planned naps are effective in maintaining performance during periods of more than 24 hours of total sleep deprivation,[224] and are most effective when occurring about two-thirds of the way through a period of sleep deprivation and lasting about 20 minutes.[225,226] Consumption of approximately 100mg of caffeinated gum after waking can minimize grogginess after waking from a scheduled nap during a shift.[227] Based on this research, it is recommended that military commanders consider planned or rotational naps for their personnel during identified periods of sleep deprivation.

A recent body of research suggests that getting extended sleep prior to known periods of sleep deprivation ("sleep banking") can have benefits on performance among sleep-deprived individuals.[228] For example, by getting ten hours of sleep per night prior to a period of partial sleep deprivation, participants in one study showed better alertness and performance during sleep deprivation (sleeping three hours per night) than individuals who did not get additional sleep prior to the known disruption.[229] In the military context, U.S. Army Soldiers who had better subjective sleep quality prior to a period of occupationally mandated sleep loss had greater physical resilience to the sleep loss, suggesting Soldiers with better quality sleep may have naturally obtained banked sleep.[230] In order to implement significant sleep banking, military commanders must ensure that additional sleep is allowed and encouraged during the ramp-up preparation and OPTEMPO period prior to a mission.[231] Following periods of high OPTEMPO, commanders should support sleep extension (i.e., affected Service members sleeping more than eight hours per night) in order to restore baseline sleep.[232]

Mitigating the Effect of Sleep Deprivation on Physical Performance

Sleep loss affects physical performance and capabilities. A study of a sample of U.S. Army Soldiers who train others on mountain warfare techniques found that the trainers had poorer balance (a proxy of higher injury risk) following sustained operations (SUSOPS).[233] Furthermore, findings from two samples of U.S. Army Rangers demonstrated a significant reduction in testosterone, which is critical for muscle recovery after physical activity, following military exercises requiring sleep loss.[234]

A variety of factors may contribute to the degree to which sleep deprivation influences physical performance, such as the timing of the sleep restriction, and whether opportunities exist for sleep restoration. For example, athletes who had a single night of partial sleep deprivation at the end of the night (i.e., rising four hours early) experienced reduced muscle strength and power the following afternoon; however, those whose sleep deprivation occurred at the beginning of the night (i.e., delayed bedtime by four hours) experienced no such reductions.[235] Napping prior to physical training might help restore cognitive function and maintain lifting performance in compound movements after sleep deprivation.[236] For example, preliminary research with Swedish Armed Forces cadets who had undergone partial sleep deprivation (five hours of sleep during a 51-hour period) found that taking a 30-minute nap prior to exercise was associated with significant increases in the number of lunges completed in two minutes.[237] Preliminary research (typically lacking proper experimental controls) on extending time in bed prior to specific events among athletes has shown beneficial effects on reaction times, sprint times, accuracy of tennis serves, and successful three-point basketball shots.[238] Thus, prior sleep extension may benefit Service members who engage in a military operation that requires peak physical performance.

Addressing Caffeine Use

Caffeine consumption, particularly through energy drinks, is pervasive in the military.[239,240,241] Although potential short-term benefits exist when using caffeine as a countermeasure for the effects of total and partial sleep deprivation, the effectiveness of caffeine supplement use on the battlefield to augment wakefulness during periods of sleep deprivation is unclear, if combined with the typical amount of caffeine consumed by Service members through coffee, energy drinks, and other supplements.[242] Most studies of operational use of stimulants tightly control the amount of caffeine consumed by participants.[243,244] Similar to flight medicine, commanders must be aware of the amount of caffeine consumed by their Service members in operational settings, and enforce limits when acute or chronic consumption of this drug exceeds the cost-benefit threshold.[245] The most consistent findings indicate that limiting controlled administration to 200mg per dose is the most effective in maintaining performance during partial sleep deprivation.[246] Routine daily caffeine use should not exceed 400mg, and emergency use of caffeine to combat total sleep deprivation due to operational necessity should not exceed 1000mg.[247,248,249] Caffeine countermeasures cannot replace the need for sleep; the overuse of this stimulant drug in military settings will disrupt chronic sleep patterns and increase levels of sleep deprivation.[250,251]

Mitigating Travel-Related Circadian Rhythm Disturbances

Research literature includes a number of specific, well-established techniques to mitigate effects of travel-related circadian rhythm disturbances.[252] These include maintaining hydration prior to travel, shifting early to the destination sleep schedule, adhering to destination sleep timing upon arrival, limiting naps to 20–30 minutes in duration, and aligning light exposure with travel direction (morning for eastward, evening for westward).[253] Units deploying across six or more time zones should allow at least two weeks of adaptation time to mitigate any physical and cognitive effects of circadian rhythm disturbances.[254] Despite some inconsistent results, melatonin taken one to two hours before sleep may help facilitate time zone transitions for eastward travel, when taken as part of a comprehensive sleep plan.[255] Furthermore, melatonin use has relatively low occurrence of adverse events, indicating it is a safer option for adjusting circadian rhythms than sedative-hypnotics.[256]

Interventions to Improve Sleep

Several interventions are available to restore a regular sleep cycle for Service members who are experiencing chronic partial sleep deprivation. Behavioral interventions are preferred as a first-line treatment in both primary and secondary care settings, and have more lasting effects than pharmaceutical interventions.[257] Brief Behavioral Treatment for Insomnia[258] and Cognitive-Behavioral Therapy for Insomnia[259] are empirically supported techniques for mitigating chronic partial sleep deprivation and re-establishing a regular sleep cycle. These behavioral interventions are also the front-line intervention for sleep disruption related to mental health conditions, including depression, TBI, and PTSD.[260,261] The Defense Health Agency has piloted and will further implement a specific Primary Care Sleep Improvement Clinical Pathway that ensures training for all primary care behavioral health consultants in the delivery of behaviorally based treatments for insomnia. Initial results show these interventions can be effectively modified for the military operational environment, including use of remote consultation via internet or telephone.[262,263,264] Furthermore, addressing sleep-related issues in primary care settings may be a pathway for preventing the onset of depression or anxiety symptoms among Service members who may hesitate to seek mental health treatment.[265]

Mobile Applications for Sleep Management

To enable direct use of sleep management tools by Service members, military leaders should actively promote existing mobile applications developed by the DoD and the Department of Veterans Affairs.[266] Service members should not leave basic training without these sleep management mobile applications installed on their smartphones. The following mobile applications and related digital tools are available at no cost, and are based on empirically supported interventions:

- The Breathe2Relax mobile application can promote sleep onset by decreasing physiological arousal through relaxation exercises.[267] Its parallel version—the Tactical Breather—was designed specifically for use in military field settings.

- The Military Meditation Coach podcast similarly provides Service members with relaxation scripts to promote better sleep for use in any setting. These scripts were developed specifically as part of the Navy Mind-Body Medicine program.[268]

- The CBT-I Coach mobile application allows Service members to track nightly sleep, identify patterns of sleep deprivation, and receive useful feedback to improve sleep behavior.[269]

- The DreamEZ mobile application assists Service members in Imagery Rehearsal Therapy, an empirically supported treatment for reducing nightmares related to traumatic events.[270]

- The 2B-Alert web and smartphone application was specifically designed to predict the effects of sleep deprivation and provide guidance on how to optimize sleep schedules and caffeine dosing for any given sleep/wake schedule.[271]

Current Lines of Effort in Military Sleep Research

Military research labs and academic partners are engaged in several ongoing lines of research aimed at mitigating the occurrence and impact of sleep deprivation among military personnel. These efforts include:

- Enhanced fatigue management tools intended for use at the individual Service member and squad levels.
- Cutting-edge assessment of the effects of sleep deprivation on brain physiology (to identify highly specific targets for development of next-generation interventions to sustain performance and brain health).
- Nutritional supplements and pharmacology that facilitate fatigue management, including novel formulations of existing products.
- Transcranial electrical stimulation to mitigate performance degradation and improve recovery time following sleep deprivation.
- Acoustic stimulation to mitigate performance degradation and improve recovery time following sleep deprivation.
- Ruggedized technologies to track sleep and performance in operational environments.
- Command policy and training to enhance sleep leadership.

Future research priorities include:

- Optimization of interventions to promote a healthy sleep-wake cycle in operational environments.
- Development of sleep strategy interventions (e.g., tactical combination of nocturnal sleep and daytime napping schedules) to maximize performance and alertness in operational environments.
- Identification of novel biomarkers that reflect and quantify an individual's extant level of sleep debt, and its implications for health and performance.
- Further development of ruggedized technologies for fatigue management on the battlefield.
- Development of individualized and unit-level technology for non-intrusive and non-invasive monitoring, prediction, and prevention of fatigue-related performance decrements.
- Development of countermeasures to prevent and/or reverse circadian misalignment to

maximize human performance during Multi-Domain Operations.

CONCLUSION

Sleep deprivation is common in the military, and impacts military performance and readiness. Numerous factors, alone or in combination, can result in sleep deprivation, including operations in austere environments not conducive to sleep, nighttime operations, sleep pathologies, and several psychiatric conditions. It is recommended that the DoD establish policy to promote a culture shift with regard to prioritizing adequate sleep in the military. In summary:

- Duty schedules must be adopted to ensure eight hours of sleep.

- Unit-level sleep trainer positions should be established.

- Training in sleep leadership should be implemented.

- Education and other steps should be taken to decrease caffeine use.

- Existing research-based strategies should be adopted to address travel-related circadian rhythm disruption.

- Use of brief behavioral interventions and mobile applications for sleep disruption should be expanded.

- A clearinghouse for military sleep-related resources should be established.

Adequate sleep is a key component of readiness. Although military leaders are increasingly recognizing the importance of adequate sleep, further shifts in cultural attitudes regarding sleep deprivation will help ensure the optimization and sustainment of Service member performance and health.

ACRONYMS

BIISS	behaviorally-induced insufficient sleep syndrome
DoD	Department of Defense
FY	fiscal year
MHS	Military Health System
OPTEMPO	operations tempo
PTSD	posttraumatic stress disorder
TBI	traumatic brain injury

DEFINITIONS

Operations Tempo	The rate of U.S. military involvement in all military activities or unit activity. Tempos are too high or low if they cause forces to lose their capacity to sustain operations and meet crises. The most significant negative impact of tempos that are too high is the reduction in time and resources for relevant, necessary training—the basis of readiness and long-term effectiveness.
Sleep Deprivation (Military)	Inadequate sleep that negatively impacts a Service member's military effectiveness due to a reduced ability to execute complex cognitive tasks, communicate effectively, quickly make appropriate decisions, maintain vigilance, and/or sustain a level of alertness required to carry out assigned duties.
Sleep Deprivation (Partial)	At least one night of interrupted or partial sleep, typically operationalized as less than seven hours of sleep per night for adults.
Sleep Deprivation (Total)	A period of continuous wakefulness that exceeds 24 hours, or getting zero sleep time during the typical sleep-wake cycle.
Sleep Deprivation (Chronic)	Partial sleep deprivation with at least one week during which an individual receives less than seven hours of sleep on most nights and is unable to get sufficient recovery sleep to make up for lost sleep time.
Sleep Disruption	Fragmented sleep due to periods of brief arousal, breathing interruptions, or other mid-sleep awakening.
Sleep Banking	Receiving extended sleep prior to known periods of sleep deprivation.
Sleep Trainer	Unit-level personnel trained to facilitate sleep plans, monitor individual sleep performance, and train unit members on behavioral strategies for minimizing and mitigating sleep deprivation.

ATTACHMENT 1: SUBTYPES OF SLEEP DEPRIVATION

Total Sleep Deprivation

Human studies demonstrate that total sleep deprivation negatively affects almost all cognitive domains.[272] Total sleep deprivation worsens performance the longer an individual goes without sleep, and is related to deficits in attention, processing speed, accuracy, short-term and long-term memory, decision-making, and reaction time.[273] A meta-analysis shows that each successive day of total sleep deprivation results in a 22 percent decrement in task accuracy at night and a seven percent decrement in task accuracy during daylight hours.[274] In addition, total sleep deprivation significantly increases acute anxiety, decreases the ability to regulate emotions, and increases the stress response, with worsening effects over 24–36 hours of total sleep deprivation.[275] Neuroimaging studies suggest that total sleep deprivation has the same overall effects on the brain as clinically significant symptoms of attention-deficit/hyperactivity disorder.[276] Occupational studies indicate that total sleep deprivation decreases self-control, while increasing hostility, risk-taking behavior, and deviant workplace behaviors (such as theft).[277] Furthermore, studies show that total sleep deprivation negatively affects several domains related to routine work duties, such as receptive and expressive speech, memory, and verbal arithmetic.[278] Thus, a Service member with total sleep deprivation may be at greater risk of not fully comprehending verbal instructions, remembering what was said in mission briefings, and having greater difficulties articulating instructions when giving orders.

Studies of Service members demonstrate an association between significant declines in military performance and total sleep deprivation. Overall estimates suggest that each 24-hour period of total sleep deprivation results in a 25–35 percent degradation of cognitive task performance.[279,280] Among Navy SEAL Candidates, marksmanship speed and accuracy significantly worsen after three days of total sleep deprivation.[281] Soldiers with two days of total sleep deprivation show significant decreases in marksmanship accuracy (61 percent overall) and vigilance during urban operations (44 percent overall), with delayed reaction time for all tasks.[282] A study of active duty military personnel demonstrated that more than 48 hours of total sleep deprivation resulted in significant judgment impairment in moral scenarios, particularly in emotionally charged situations.[283] One night of sleep deprivation among F-117 pilots degrades basic piloting skills by more than 40 percent.[284] Other research shows that United States Military Academy cadets undergoing 24 hours of total sleep deprivation demonstrate significant deficits in learning to differentiate stimuli, which can have implications for differentiating types of intelligence data or identifying whether a battlefield target is an ally or adversary.[285] Over a 53-hour training period with only three hours of sleep, Soldiers showed significant decreases in cognitive functioning, to include attention, memory, and reasoning, as well as significant symptoms of confusion and depression.[286] Research conducted with Australian Army personnel undergoing 40 hours of total sleep deprivation also replicated previous findings, which demonstrated that several executive functions—to include inhibitory control, task-switching, and vigilance—deteriorate with total sleep deprivation.[287] These results indicate that sleep deprivation can compromise core capabilities underlying military decision-making. Total sleep deprivation can also have consequences that are more serious; reports from Norwegian officers show that hallucinations are common during extended periods of total sleep deprivation.[288] Taken together, these findings clearly demonstrate that sustained operations involving total sleep deprivation negatively affect military performance.

Partial Sleep Deprivation

Partial sleep deprivation, also called sleep restriction, is more common than total sleep deprivation. It can have noticeable effects following sleep reduction by only one hour per night; these effects become far more pronounced when sleep is restricted to less than four to five hours per night.[289] Chronic partial sleep deprivation has been linked to a number of neurobehavioral deficits, including attention lapses, slowed working memory, longer reaction time, thought perseveration, and depressed mood, which can accumulate over several days to the same levels after one–three nights of total sleep deprivation.[290,291,292] A meta-analysis shows that partial sleep deprivation primarily affects executive functioning, sustained attention, and long-term memory, but may have more variable impact on multitasking, impulsive decision making, and problem solving.[293] The overall effect of partial sleep deprivation on cognitive functioning is more pronounced if sleep deprivation is a loss of five or more hours of sleep per night (an 11 percent decrement), compared to a loss of two to five hours of sleep (a nine percent decrement), and a loss of less than two hours of sleep (a three percent decrement).[294] This meta-analysis also indicates that over the course of one week, individuals typically experience a one percent loss in task accuracy for each night of partial sleep deprivation, when getting five to six hours of sleep per night, and a seven percent loss in task accuracy for each night of partial sleep deprivation, when getting three to four hours of sleep per night.[295] Demographic factors may affect overall decrements associated with partial sleep deprivation. Within the military age range, cognitive deficits due to partial sleep deprivation significantly increase with age, while partial sleep deprivation has a lesser effect on sustained attention among women than men.[296]

Partial sleep deprivation compromises an individual's emotional self-regulation abilities.[297] Those with partial sleep deprivation experience greater levels of stress and anger when engaging in low stressor tasks than those who are not sleep deprived.[298] Other research shows that complex cognitive task performance, such as working memory and team performance, deteriorates the longer individuals undergo sleep deprivation, which creates a specific risk for the impact of sleep deprivation when managing unexpected emergencies.[299] This is especially concerning in a military operational environment, where unit leaders often face significant and unexpected crises. If these leaders are sleep deprived, it is likely that their reasoning abilities, problems solving skills, and communication abilities are compromised, placing the mission and Service members' lives at risk.[300]

Specific to military contexts, partial sleep deprivation has a significant impact on mission-related performance. In the combat environment, 28 percent of Service members reported falling asleep during convoy operations, 13 percent reported falling asleep during mission briefings, and eight percent of Service members reported falling asleep while on guard duty.[301] Drowsiness is also a significant cause of accidents in combat and training environments. For example, 46 percent of Army drill sergeants reported falling asleep while supervising trainees, which could lead to injuries and accidents during rifle marksmanship, obstacle courses, or land navigation.[302] Approximately 40 percent of deployed Service members with less than seven hours sleep per night reported a safety-related accident due to sleepiness, of which 21.7 percent of Service members reported three hours of sleep or less.[303] In a sample of Army aviation personnel who received an average of less than seven hours of sleep per night, 72 percent reported they had flown when drowsy enough to compromise safety, while 45 percent reported they had "dozed off" while flying or in the cockpit.[304] A subsequent study of Army aviation personnel also identified that 49 percent of the study sample slept less than necessary, while 21 percent reported "dozing off" while flying.[305] In a field training environment, increased sleep deprivation among Marines directly predicted worse performance on obstacle course tasks.[306] U.S. Army field training data suggest that effectiveness in key combat task performance degrades by 15–25 percent for each hour of partial sleep deprivation per night; an estimated 15 percent of total combat effectiveness results when Soldiers sleep only four hours per night.[307] Sleep deprivation may also affect military leadership. Norwegian officer cadets averaging two to three hours of sleep per night during combat survival exercises showed significant decreases in transformation and transactional leadership behavior, but significant increases in passive-avoidant leadership behavior.[308]

ATTACHMENT 2: IMPACT OF SLEEP DEPRIVATION IN SPECIFIC MILITARY CONTEXTS

A number of specific military contextual factors relate to the prevalence of sleep deprivation. These factors include travel crossing multiple time zones, maladaptive sleep practices in operational settings, and inhospitable sleep environments.

Travel Crossing Multiple Time Zones

Approximately 60 percent of individuals crossing at least two time zones experience circadian rhythm disturbances or "jet lag" for at least one day following travel.[309] When travelling east, an individual will typically experience problems with falling and staying asleep; for westbound travel, individuals typically experience problems staying asleep for the entire night.[310] This circadian rhythm disturbance results in partial sleep deprivation, typically between 30 minutes and two hours.[311,312,313] A number of factors predict the severity and duration of circadian rhythm disturbance and accompanying partial sleep deprivation. A more significant effect is seen for westbound travel, longer flight duration, greater number of time zones crossed, and more hours of sleep lost during travel, as well as among older individuals.[314] Total sleep time and fatigue also may increase after travel across multiple time zones due to travel-related disruptions and poor sleep environment.[315] Scheduling of flights also plays a role in sleep deprivation related to crossing multiple time zones. If passengers travel on overnight eastbound flights (i.e., "red-eye" flights, or international flights that arrive early in the morning in the destination time zone), then they will tend to have a greater number of hours of sleep deprivation before sleeping the next night than typical westbound flights (which arrive late in the day).[316] Travel-related circadian rhythm disturbances most frequently result in poor sleep and appetite loss, with consequent tiredness during the day and poorer occupational performance.[317,318] Studies consistently show that jet lag results in diminished performance on physical tasks, particularly during the first 72 hours, even with sufficient sleep time.[319,320,321] Studies among high-performance athletes suggest that physical and mental adaptation to the new time zone requires one half day per hour of time difference when traveling west, and one full day per hour of time difference when traveling east.[322,323] As a corrective strategy, reviews of the literature differ on whether exogenous melatonin facilitates adjustment to new time zones.[324,325,326]

Mission-Related Maladaptive Sleep Practices

Occupational duty requirements may be the most prominent factor driving chronic partial sleep deprivation among Service members. Unplanned and ad-hoc shift work, unpredictable schedules, 24-hour duty assignments, and manning shortages all can result in sleep deprivation among Service members.[327] In both deployed and garrison settings, military personnel face extended duty hours in order to accomplish all maintenance, training, and administrative duty requirements.[328] When deployed, between 15 and 21 percent of Soldiers report that high operations tempo (OPTEMPO) results in partial or total sleep deprivation.[329] Service members in all branches report significantly greater rates of sleep deprivation during duty days (65 percent reporting less than seven hours of sleep per night) compared to weekends (21 percent reporting less than seven hours of sleep per night), indicating that the planned duty day plays a significant role in sleep deprivation.[330] A significant percent of Service members (36–38 percent of Soldiers and 27–33 percent of Marines) indicate that the length of the duty day provides insufficient time to complete personal business, resulting in restricted opportunity to sleep.[331] Related to this finding, only five to six percent of Service members report that off-duty leisure activities (such as video games) contributed to sleep loss in deployed settings.[332] Certain leader assignments also may impose sleep deprivation due to occupational demands. For example, 93 percent of U.S. Army drill sergeants report getting six or fewer hours of sleep per night while typically working more than 14 hours per day for at least six days per week.[333]

Although sleep deprivation in the military has been compared to related occupational categories, military Service members (55–76 percent) report significantly greater rates of partial sleep deprivation than firefighters (46 percent), law enforcement officers (40 percent), and healthcare professionals (40 percent).[334] In fact, active duty military personnel were excluded from the nationwide American Time Use Survey that assessed sleep due to the fact that military occupational requirements would disrupt normal sleep schedules, when compared to the general U.S. population.[335] Culturally, maximum performance while sleep deprived has been touted as a key skill for military personnel, and that operating on restricted sleep demonstrates toughness.[336,337] Attitudes toward sleep among military commands range from viewing sleep as a controlled ration to asserting that a need for sleep is a sign of weakness.[338] Despite reporting significant sleep deprivation, only a minority of Service members indicate sleep deprivation affects their overall job performance.[339] Army surveys from 2009–2013 show that 27–34 percent of Soldiers reported significant concern about not getting enough sleep, although this rate has significantly decreased over time.[340] Nonetheless, 56 percent of Service members indicate that they get less sleep than needed to perform their military duties well.[341] Leadership also plays a significant role in whether Service members in a given unit suffer from partial sleep deprivation. U.S. Army surveys indicate that only 26 percent of leaders encourage Service members to get adequate sleep, 24 percent work to ensure an adequate sleep environment, and 35 percent consider sleep as an important factor in operational planning, such as establishing an adequate shift rotation that ensures sufficient sleep.[342]

A number of studies investigated the impact of shift work in military populations. While deployed, between 32 and 40 percent of Soldiers report that nighttime duties significantly affect sleep.[343] Air Force night shift workers report significantly greater sleep problems than day shift workers.[344] A comparison of duty watch schedules among Navy personnel showed that the five-hour on ten-hour off duty watch schedule resulted in significantly more sleep per day (6.9 hours of sleep) compared to six-hour on/six-hour off (5.9 hours of sleep) or modified six-hour on/eighteen-hour off (5.7 hours) duty watch schedule, but equivalent to a three-hour on/nine-hour off (6.5 hours of sleep) duty watch schedule.[345] However, the rotating circadian pattern of the five-hour on/ten-hour off duty watch schedule caused a recurrent pattern of changing sleep time that also resulted in repeated instances of Sailors getting only four hours of sleep prior to a 20–22 hour period of sustained wakefulness.[346] Furthermore, Sailors on the five-hour on/ten-hour off and six-hour on/six-hour off duty watch schedules showed decrements in psychomotor vigilance compared to the other schedules.[347] Another evaluation showed that Navy personnel preferred eight-hour duty shifts to twelve-hour duty shifts, with eight-hour shifts associated with fewer errors in tasks requiring psychomotor vigilance, although both shifts generally entail less than seven hours of sleep per day.[348] Similar research examined shift cycles and sleep onboard submarines. Without light controls on an 18-hour duty submarine cycle, Service members did not show regular sleep and wake patterns, demonstrating that social cues (e.g., meals, clocks) were insufficient to establish circadian rhythm.[349] However, a comparison of the 18-hour duty schedule (6-hour on/12-hour off) to a compressed schedule designed to synchronize with the 24-

hour clock demonstrated that crew members tended to sleep more on the 18-hour schedule (7.1 hours per night) than the 24-hour schedule (6.3 hours per night).[350] A study of a French submarine crew on a three-day (72 hour) shift rotation that included 28 hours set aside for sleep with specific light level controls showed that members were able to maintain total sleep time between 6.5–7 hours of sleep per night throughout a 70-day period.[351] Other evaluations have shown that Army aviation personnel assigned to the night shift frequently report working between 10–14 hours per shift, and typically get less than six hours of sleep per night.[352] In contrast, adhering to strict safety standards to ensure adequate sleep between duty shifts can significantly affect reported sleep deprivation. Data from the Behavioral Risk Factor Surveillance System show that air transportation workers in the United States, who must adhere to federal standards for sleep between shifts, have one of the lowest rates (21 percent) of reported sleep deprivation.[353] Taken together, these findings suggest that scheduling specific time in the duty day for sufficient sleep may be the best method of maintaining 24-hour operations without contributing to sleep deprivation.

A specific type of military readiness involves the ability to execute sustained operations (SUSOPS), which involve exposure to extreme situations and severe environmental conditions for several days without the opportunity for full physical recovery to baseline (i.e., sleep or nutrition).[354] The intent of SUSOPS is to simulate the demands of potential combat situations that would not allow for scheduled rest or meals for a period of two to seven days.[355] Studies on the effects of SUSOPS typically have examined partial to total sleep deprivation, with less than three hours of uninterrupted sleep over a period of up to nine days.[356] Reviews show that SUSOPS exercises significantly decrease task vigilance, reaction time, reasoning ability, and working memory, with a consistent decrement in performance by 25 percent for each day of near-total sleep deprivation.[357,358] In addition, SUSOPS increase risk of bone fractures, loss of muscle mass, and sleep-related physical decrements.[359] Although 24-hour operations have become the norm for the U.S. military over the past two decades, it is important to note that 24-hour operations are not analogous with SUSOPS.[360] Whereas SUSOPS training may be required to establish capability, it must not be assumed that Service members can function regularly in a SUSOPS environment. Regular 24-hour operations require sufficient sleep periods to ensure that Service member performance and readiness do not degrade.[361,362,363] If a period of SUSOPS is required for two to three days due to emergency or disaster relief situations, Service members require at least a 12-hour sleep recovery period during nighttime hours to restore normal functioning.[364] In a mature battlespace, SUSOPS should not be required except in emergency situations, and military commanders should be able to establish regular sleep cycles for their units.[365,366]

Uncomfortable and Inhospitable Sleep Environments

Due to the nature of military operations in austere locations worldwide, a number of environmental factors in combat, training, and operational settings may contribute to sleep deprivation.[367] Between 27 and 35 percent of deployed Army personnel surveyed during 2010–2013 reported that poor sleep environment impacted their ability to get sufficient sleep.[368] Although Service members may be encouraged to "sleep whenever you can" in operational settings, it is unlikely that sleeping in tactical vehicles, military aircraft, large transient tents or hangars, or near machinery is restorative.[369] Deployed Air Force personnel reported that loud noise outside sleeping tents, uncomfortable beds, loud noise inside sleeping tents, and uncomfortable heat/cold were the most common environmental factors that affected sleep.[370] A study among deployed aircrews from the Royal New Zealand Air Force similarly reported that decibel levels and temperatures in the sleeping quarters exceeded comfortable levels frequently overnight and regularly during the daytime.[371]

Ambient temperature is an important environmental factor that can contribute to partial sleep deprivation.[372] When deployed to warmer climates, Service members may require several days for the regulation of their core body temperature to normalize, which results in partial sleep deprivation.[373], Summer nighttime temperatures in Iraq and Afghanistan during Operation IRAQI FREEDOM and Operation ENDURING FREEDOM frequently exceeded ideal ranges for sleep initiation.[374,375] When daytime temperatures in the deployed environment exceed 90°F, most base construction projects occur at night; however, this causes significant noise that disrupts the sleep of Service members in tents.[376] Furthermore, most U.S. military basic training sites are in locations with daytime temperatures exceeding 90°F for more than 50 days per year, potentially contributing to sleep deprivation among trainees.[377] Due to the impact of extreme temperatures on sleep deprivation among Service members, air conditioning infrastructure is critical in deployed and field settings.[378] Conversely, military trainees also report they receive insufficient bedding to stay warm during the night in barracks, which contributes to partial sleep deprivation.[379]

Occupational factors also can interact with environmental factors to worsen sleep deprivation. Problems caused by shift work during 24-hour operations can be exacerbated by light and noise contamination, if crew sleeping areas are not set aside from daytime operation personnel, not adequately blacked out to ensure darkness, or are still used for mission-related tasks (such as obtaining keys or log books).[380] In initial entry settings, trainees reported several factors that disrupt sleep, such as excessive noise in communal sleeping areas, light contamination from security lights, and rotational nighttime duties that woke both the trainees and their bunkmates.[381] Furthermore, co-location of crew sleeping areas with work areas—such as flight crews sleeping near the airfield—tends to contribute to significant sleep disruption due to noise in 24-hour operational environments.[382] All of these factors suggest that maintaining adequate sleep for personnel should be a primary consideration in establishing operational rotations, work locations, and standard operating procedures.

ATTACHMENT 3: PHARMACOLOGICAL INTERVENTION TO SUPPORT OPERATIONS TEMPO

Caffeine

On average, Service members consume approximately 212mg to 285mg of caffeine per day, with significantly greater consumption among men than women.[383,384,385] In comparison, U.S. adults consume an average of 165mg–210mg of caffeine per day.[386,387,388] However, rates of caffeine consumption among military recruits appear to be generally comparable to high school and college samples.[389] Reviews on the health effects of caffeine suggest that daily consumption of 400mg of caffeine or less is typically safe.[390,391] Military recommendations for maximum daily caffeine intake range from 400mg–1000mg, but acknowledge that subsequent side effects may occur.[392,393,394] Caffeine can be lethal at overdose levels of 10,000mg or higher.[395] Doses of 400mg of caffeine have been shown to cause partial sleep deprivation of at least one hour, if consumed up to six hours before bedtime.[396]

Evidence synthesized from across military and civilian studies demonstrates some support that moderate doses of caffeine (approximately 300mg) can maintain levels of alertness, attention, vigilance, and reasoning during sleep deprivation.[397,398] Nonetheless, caffeine may not have comparably positive effects on memory, judgement, or decision making during sleep deprivation.[399,400] In addition, caffeine doses over 200mg show positive effects on physical performance, including time-trial or sprint speed, muscle strength and endurance, and time-to-exhaustion.[401] Caffeine use may need to be monitored or limited during periods of prolonged sleep deprivation. For example, although caffeine can improve functioning temporarily during sleep deprivation, 300mg of caffeine is generally no better than 200mg for restoring cognitive performance during 48 hours of total sleep deprivation.[402] This suggests that for most people and under most conditions, a dose of 200mg caffeine may occupy the majority of available adenosine receptors in the brain, so that doses in excess of 200mg provide diminishing returns. A number of military studies examined the use of caffeine to ameliorate the effects of partial and total sleep deprivation during training and operational tasks. In field training settings, several positive effects of caffeine have been identified. In a study of SEAL candidates with 72 hours of near-total sleep deprivation, doses of 100mg to 300mg of caffeine did not improve marksmanship, but doses of 200mg and 300mg of caffeine significantly improved vigilance, reaction time, and alertness compared to a placebo condition.[403] Similarly, in studies of special forces personnel undergoing field training, 200mg doses of caffeine maintained vigilance during overnight field observation tasks compared to placebo, as well as improving four-mile run times; however, marksmanship accuracy and speed were not affected by caffeine.[404,405,406,407] Several of these findings also have been replicated in international military settings.[408] Physical performance during field tasks while sleep deprived also can be maintained with caffeine, such as findings that a 600mg dose of caffeine helps sustain performance during a forced march, treadmill run, and sandbag piling task.[409] In contrast to studies showing no effect of caffeine on marksmanship, only one study has shown that caffeine maintained marksmanship performance compared to placebo during sleep deprivation, although this may have been due to factors such as caffeine-related enhancement of "sighting time" or "target selection" (i.e., factors that vary from study to study) rather than differences in shooting accuracy, per se.[410,411,412,413]

Caffeine formulation may also be an important consideration for military operations, especially when caffeinated drinks are unavailable. Studies using caffeine gum have shown that administration can be effective for minimizing fatigue after being awakened in the middle of the night, and that caffeine gum can significantly reduce the negative effects of partial sleep deprivation on alertness and performance for at least three days.[414,415] Several studies among the French Armed Forces suggest that slow-release caffeine capsules are effective in maintaining cognitive performance during total sleep deprivation of 2–3 days, including positive effects on reaction time, attention, and executive functioning without negative effects on subsequent recovery sleep. [416,417,418]

Studies among aviation personnel have shown less consistent results. A study of 111 combat operation sorties showed that 86 percent of F-15E aircrew regularly used caffeine (with typical daily doses of 200–300mg), 63 percent of sorties were conducted after consuming caffeine, and caffeine was used during flight in 13 percent of sorties.[419] In a study of U.S. Air Force pilots in a U2 simulator, two doses of 200mg of caffeine (400mg total) allowed pilots to maintain cognitive task performance during a 9-hour total sleep deprivation period.[420] However, 200mg doses of caffeine did not reverse the decrements in flight simulator performance among Finnish military pilots after 37 hours of sleep deprivation; although pilots receiving caffeine reported overconfidence in performance, and overestimated their own performance level.[421,422] These findings notwithstanding, the intent of controlled caffeine administration in these settings is to maintain operational performance at typical levels when Service members are sleep deprived.[423] The efficacy of caffeine and other psychostimulants is transient, and can delay—but not replace—the need for sleep.[424] The positive effect of caffeine on performance maintenance during sleep deprivation has only been identified over a 48–72 hour period of continuous wakefulness. Thus, the findings reviewed should not be generalized to settings in which Service members are continuously ingesting caffeine at the same levels (such as through energy drinks) over extended periods of partial sleep deprivation.[425,426] Other studies suggest reduced effectiveness of caffeine following consistent dosing for three days of partial sleep deprivation.[427] High doses of caffeine also can affect subsequent recovery sleep following total sleep deprivation.[428] Overuse or misuse (e.g., too close to bedtime) of stimulants in military environments can disrupt sleep patterns, resulting in a greater need for caffeine during the day to stay awake, potentially creating a "vicious circle" of increasing use of caffeine in the daytime prompted by increasingly caffeine-disrupted nighttime sleep.[429]

Energy Drinks

Although coffee is the most prevalent source of daily caffeine among Service members overall, energy drinks are the most common source among younger Service members.[430] Energy drinks are considered dietary supplements, with caffeine content typically ranging from 80–300mg per serving.[431] Data from the National Health and Nutrition Examination Survey (NHANES) shows that 2.7 percent of the general U.S. population regularly consumes energy drinks, with the highest use (7.6 percent) among younger men (ages 19–30).[432] In contrast, studies show significantly higher rates of energy drink consumption in the U.S. military. For example, a survey of military personnel in operational, training, and medical settings found that 53 percent of Service members consumed at least one energy drink in the past 30 days, and 38 percent consumed an energy drink one or more times per week.[433] U.S. Army personnel are the most frequent users of energy drinks (54 percent), and U.S. Air Force personnel (26 percent) are the least frequent.[434] Studies of U.S. Army and U.S. Marine Corps personnel stationed in Afghanistan showed that 45 to 60 percent of Service members consumed at least one energy drink per day, with five percent consuming five or more energy drinks per day.[435,436] Other deployed samples show that 43 percent of Soldiers increase consumption of energy drinks while deployed.[437] However, this trend may be the result of increased availability of certain brands of energy drinks in deployed settings, often due to contract purchasing.[438] Increases in energy drink consumption during deployment also may continue after Service members return home.[439] Although the Navy and Marine Corps prohibit consuming energy drinks prior to flying military aircraft, a significant proportion of pilot candidates report a history of utilizing energy drinks to stay alert.[440] Similarly, 41 percent of surveyed Army pilots reported regular use of energy drinks.[441]

Energy drink consumption also carries significant health risks for those who are sensitive to the effects of caffeine, or who consume excessive amounts of caffeine. Several cases of acute cardiovascular events (including cardiac arrest, myocardial infarction, spontaneous coronary dissection, and coronary vasospasm) related to energy drink consumption have been identified in the past several years, with the majority of these cases showing no prior risk of cardiac disease.[442,443] Randomized trials of energy drink consumption show that they increase blood pressure, heart rate, QTc interval, and cerebrovascular resistance, significantly stressing overall cardiovascular function.[444,445,446] Nationwide emergency room visits related to consumption of energy drinks number in the tens of thousands, and at least 34 deaths have been attributed to energy drink consumption (frequently in combination with other drugs).[447] Caffeine consumption at the levels commonly found in energy drinks also can significantly contribute to insomnia and associated partial sleep deprivation.[448] Service members who regularly use energy drinks frequently report problems sleeping, although it is unclear whether this energy drink use is the cause of partial sleep deprivation or in response to partial sleep deprivation.[449] Among Service members in Afghanistan, those consuming three or more energy drinks per day were significantly more likely to report sleeping four or less hours per night.[450] Sixty percent of Soldiers who report being on sleep medications also report consuming at least one energy drink per day, compared to a significantly lower proportion of Soldiers (43 percent) who are not on sleep medications but report daily energy drink consumption.[451] In contrast to studies on carefully dosed caffeine during military tasks, energy drinks likely provide an irregular dose of caffeine at various intervals, possibly nullifying potential benefits and exacerbating operational risk. Furthermore, given that many energy drinks contain several active substances in addition to caffeine, the effects of these supplements, either alone or in combination with caffeine, have yet to be fully identified.[452]

Modafinil and Dextroamphetamine

The prescription drug dextroamphetamine is approved for use under the direction of a flight surgeon in U.S. Army, U.S. Navy, U.S. Air Force, and U.S. Marine Corps aviation.[453,454,455,456] The prescription drug modafinil is also approved for use under the direction of a flight surgeon in the U.S. Air Force, depending on specific Major Command guidance.[457] A recent study on the prevalence of these drugs in combat aviation operations showed that pilots used either dextroamphetamine or modafinil in 35 percent of combat sorties.[458] Research on these psychostimulants generally shows that they are safe and effective in counteracting fatigue during combat or other emergency situations, especially when strict dosing and recovery sleep guidelines are followed.[459] Studies on the use of modafinil have generally shown that this drug restores and sustains (for several hours) performance during total sleep deprivation. Doses of modafinil from 200mg to 400mg have been effective in maintaining performance on cognitive tasks after 48 hours of total sleep deprivation.[460] In a study of U.S. Army helicopter pilots, a 200mg dose of modafinil maintained flight simulator performance after 40 hours of total sleep deprivation.[461] A similar study of U.S. Air Force F-117 pilots showed that three 100mg doses of modafinil maintained flight performance during 37 hours of total sleep deprivation.[462] A combined analysis of five studies of military pilots across various settings showed that modafinil and dextroamphetamine each were effective in counteracting the performance decrementing effects of sleep deprivation.[463] Similarly, a study of military helicopter pilots during flight operations with total sleep deprivation of 40 hours showed that modafinil and dextroamphetamine each were effective in maintaining alertness, cognitive functioning, and overall performance.[464] When directly comparing modafinil to dextroamphetamine and caffeine, research has shown that each of these drugs is effective in counteracting fatigue associated with total sleep deprivation, but also that each remains effective for different durations, and each is differentially effective for restoring performance on different subsets of tasks.[465,466,467] These results notwithstanding, because of the abuse potential and side effects associated with these relatively strong stimulants, they should only be applied as a last resort—that is, after all other options for ensuring adequate aircrew rest (especially protected sleep time) have been exhausted.[468] Caffeine remains the only stimulant allowed for military aviation use in several countries.[469,470] Despite the consistent use of these pharmacological interventions to maximize human performance in limited military aviation settings, ethics principles advocate that such means should only be employed in emergency situations, arguing against expansion of such interventions in other military settings. [471,472,473]

Sedative-Hypnotics

Prescription sedative-hypnotic drugs have been used in military contexts. These drugs are most effective for short-term use to promote sleep in inhospitable military environments, to counteract circadian adjustment associated with jet lag, or to facilitate work shift transitions.[474] Approximately 11 percent of Service members report the use of prescribed sedative-hypnotics to facilitate sleep in deployed settings.[475] In one study of combat aviation missions, 23 percent of sorties were flown after aircrew members had used sedative-hypnotic drugs to facilitate sleep prior to missions.[476] Another study of remotely piloted aircraft operators during combat operations showed that sedative-hypnotics were effective in facilitating rapid shift changes associated with a capacity surge without significant side effects or mission impact.[477] Studies on workplace and operational applications of short-term sedative-hypnotic drug use have shown some benefits. A study of U.S. Army pilots working night shift showed that assisting daytime sleep with sedative-hypnotics resulted in better nighttime alertness and psychomotor vigilance.[478] Several other studies have shown similar benefits to sedative-hypnotic sleep facilitation prior to periods of total sleep deprivation.[479,480,481] In addition, a military study showed that sedative-hypnotic drugs significantly improved sleep under noise interference conditions.[482] These findings suggest that sedative-hypnotic medications may be useful for facilitating sleep and subsequent alertness and performance under a variety of conditions. However, these effects may not be realized with short sleep periods (less than eight hours), because performance-impairing "drug hangover" effects may outweigh the benefits obtained from the shortened, hypnotic-induced sleep.[483,484]

Sedative-hypnotics are often used to treat partial sleep deprivation related to clinical sleep conditions. Between 2009 and 2015, approximately 2.4 million prescriptions for sedative-hypnotic medications were given to active duty Service members.[485] The adjusted rate of sedative-hypnotic use significantly increased over this period among active duty Service members from approximately 6 to 8 percent.[486] This is also significantly higher than the rate of three percent among a nationally representative study sample.[487] Long-term use of sedative-hypnotic drugs by Service members to decrease sleep deprivation is not recommended.[488] Recent guidelines recommend only brief treatments with these sleep medications to help restore sleep to baseline; behavioral interventions are recommended for long-term treatment of conditions that contribute to sleep deprivation.[489] Sedative-hypnotic drugs have a wide range of side effects that can directly impact mission readiness, including daytime fatigue, dizziness, anxiety, drowsiness, depression, disinhibition, sleepwalking, impaired cognition, learning deficits, and increased risk of motor vehicle accidents.[490,491,492,493] For this reason, any use of sedative-hypnotics (other than single administration for operational transition) is typically disqualifying for deployment.[494]

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