Chapter 26

SLEEP, REST, AND RECOVERY

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INTRODUCTION

Sleep is important to every aspect of performance involving the brain. Therefore, adequate sleep, rest, and recovery (reset) are critical components of any successful military training program or operational mission. The reset process requires adequate rest and recovery time after a major physiological or psychological insult such as an intense experience or demanding work period.

Friction often exists between meeting mission requirements and obtaining adequate sleep or rest in an operational environment. Commanders naturally want to know the minimum amount of sleep or rest needed to maintain military effectiveness during missions, between missions, and for full recovery or reset.

This chapter provides military medical officers (MMOs) information needed to advise unit commanders on appropriate management of sleep and alertness in their troops. MMOs play an important role in promoting sleep health and teaching tools service members can use to maximize good sleep practices.

DEFINITIONS

Sleep represents a physiological function of the brain and is required to maintain health and performance. Exhibit 26-1 further defines sleep and provides a popular theory about sleep and wake. Rest refers to periods of time when no tasks are being performed (time off task). Performance improvement results from rest, but rest does not equal sleep. During sleep, rest occurs, but not vice versa.

There is broad agreement about what sleep is and how it can be identified and measured, but there is no consensus regarding the ultimate functions of sleep. In 1976, Naitoh observed that sleep deprivation studies have served only to "confirm repeatedly a truism: [sleep loss] makes animals and humans sleepy."[1] Although this observation remains largely true today, the past 4 decades of sleep research has produced a wealth of knowledge and some compelling hypotheses regarding the functions of sleep. For example, Tononi and Cirelli[2] hypothesize that sleep serves to prune away excess, energy-depleting synaptic connections that accrue during wakefulness, making the well-slept cortex optimally efficient—a state that manifests behaviorally as optimal alertness and cognitive performance.

Sleepiness and fatigue are frequently used interchangeably, but are best considered as distinct phenomena. Sleepiness is best defined as the propensity or readiness to initiate sleep. It varies as an interactive function of sleep debt (caused by inadequate sleep)

EXHIBIT 26-1

TWO-PROCESS THEORY OF SLEEP

"***Sleep*** is a dynamic behavior . . . a special activity of the brain controlled by precise and elaborate mechanisms."[1] Sleep serves a homeostatic function in the body and is marked by reduced consciousness, reduced response to environmental stimuli, and dreaming. Alexander Borbély, a Swiss sleep researcher, presented a model in the early 1980s to describe the regulation of the sleep–wake cycle. He proposed that this cycle is regulated by two interacting mechanisms, or processes of sleep–wake regulation[2]:

- Process C represents circadian rhythm, or the regulation of the body's internal processes and alertness levels, governed by the internal biological clock.
- Process S represents the accrual of the physiological need for sleep during wakefulness that manifests as a homeostatic drive for sleep.

1. Hobson JA. *Sleep*. New York, NY: Scientific American Library; 1989: 1.
2. Borbély AA. A two process model of sleep regulation. *Hum Neurobiol.* 1982;1(3):195–204.

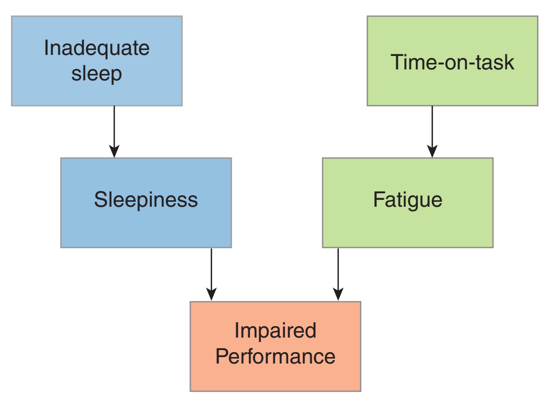

Figure 26-1. Although sleepiness and fatigue are caused by different factors, both affect performance.

and the circadian rhythm of alertness.[3] Sleepiness is marked by deficits in alertness and cognitive performance[4] related to deactivation of brain regions associated with higher order cognitive functions (eg, prefrontal cortex).[5] Sleepiness can only be reversed by sleep.

Fatigue is defined as a subjective awareness of declining abilities, due to increasing mental effort[6] that results from increasing "time on task." Fatigue may be accompanied by observable decrements in performance[7] after prolonged or repeated tasks that vary as a result of cognitive load or task difficulty and time on task.[8] Unlike sleepiness, fatigue can be reversed by "time off task."

Sleepiness and fatigue both result in performance decrements; however, these phenomena are physiologically different. Fatigue accrues as a function of "time on task," whereas sleepiness accrues as an interactive function of "time awake" and the circadian rhythm of alertness,[8] as shown in Figure 26-1. Sleepiness is reversed by sleep, and fatigue is reversed with rest.

Physicians should explore patient complaints of fatigue because patients may be using it in different ways to describe tiredness or malaise (eg, as associated with depression or diabetes). When sustained performance is required, appropriate interventions should be recommended on the basis of both "time on task" and "time awake" variables.

BACKGROUND

With mounting scientific evidence suggesting its importance for health, safety, and performance, adequate sleep has increasingly become the focus of the US military's efforts to improve and sustain the effectiveness, short-term and long-term well-being, and quality of life of service members.[9] The array of deleterious effects resulting from sleep loss is wide. One particularly important effect is impaired immune function.[10]

In the short term, acute sleep deprivation results in impaired cognitive performance including the following[11–14]:

- reduced vigilance and situational awareness,
- impaired critical thinking and problem solving,
- compromised decision-making, and
- deficits in motivation.

This impaired cognitive performance may increase likelihood of accidents and suboptimal task and mission completion. Psychological impacts such as enhanced symptoms of pain, fatigue, and negative moods may also affect well-being and job performance.

In the longer term, chronic sleep restriction has been shown to lead to impaired alertness and performance that accrues over days and weeks in a dose-dependent manner.[15,16]

In recent years, the effects of chronic sleep restriction on health and well-being have been found to include reduced resilience to stress-related disorders such as the following:

- posttraumatic stress disorder and depression,[17–21]
- cardiovascular disease,[22]
- type II diabetes,[23]
- metabolic syndrome and weight changes,[24,25] and
- mortality.[26,27]

Recent epidemiological evidence also suggests that chronic reduced sleep may predict dementing illnesses such as Alzheimer disease.[28]

MILITARY SERVICE AND SLEEP DEFICITS

Sleep disturbances are common among military personnel. Problems may begin at the start of a military career and do not discriminate by rank. Recruits at basic training as well as cadets at the service academies typically obtain less than the recommended 8 hours of sleep per night. For example, at the US Military Academy, cadets obtain an average of less than 5.5 hours of sleep per night during their 4 years of training.[29–31]

Deployed service members are impacted even more. Because modern military operations are often characterized by high operational tempos, with 24-hour-per-day activity and austere, non-sleep-conducive environments, chronic sleep restriction is widespread among deployed troops. Deployed service members report that they average significantly less than the recommended 8 hours of sleep per night,[32,33] and less than the amount of sleep obtained in garrison.[34] They report averaging less than 6 hours of sleep per night, and over half report experiencing some sleep deprivation.[35] A study of deployed US Air Force personnel revealed that 75% reported sleep that was so poor they met the diagnostic criteria for insomnia.[32] Nighttime duties and poor sleep environments are the major factors impacting sleep while deployed.[36] US Navy personnel

EXHIBIT 26-2

COMPARISON OF TRAUMA-ASSOCIATED SLEEP DISORDER WITH RAPID EYE MOVEMENT SLEEP BEHAVIOR DISORDER

Trauma Associated Sleep Disorder

- Disinhibition of voluntary muscle movement during REM sleep
- Triggered by traumatic event
- 50% comorbidity with posttraumatic stress disorder
- Repetitive dream mentation
- Dreams involve reenactment of traumatic triggering event
- No evidence of association with developing other neurologic disorders later in life
- Some success in treatment with prazosin

REM Sleep Behavior Disorder

- Disinhibition of voluntary muscle movement during REM sleep
- Spontaneous onset
- Can indicate future diagnosis of Parkinson disease

REM: rapid eye movement

Data sources: (1) Mysliwiec V, O'Reilly B, Polchinski J, Kwon HP, Germain A, Roth BJ. Trauma associated sleep disorder: a proposed parasomnia encompassing disruptive nocturnal behaviors, nightmares, and REM without atonia in trauma survivors. *J Clin Sleep Med*. 2014;10(10):1143–1148. (2) Postuma RB, Gagnon JF, Bertrand JA, Genier Marchand D, Montplaisir JY. Parkinson risk in idiopathic REM sleep behavior disorder: Preparing for neuroprotective trials. *Neurology*. 2015;84(11):1104–1113.

are no strangers to poor sleep either. Submariners, for example, report poor quality and quantity of sleep while at sea (< 6 h) compared to shore duty (~7 h) or while on leave (>7 h).[37] On surface ships, sailors who work the night shift topside and are exposed to bright morning sun just prior to bedtime (in the ascending phase of the circadian rhythm) sleep less (4.7 h) than sailors who work below deck during the night shift (7.4 h) without exposure to sunlight prior to bedtime.[38]

Furthermore, it has been shown that subjective reports of sleep duration and habituation to chronic sleep restriction are not accurate and do not reflect physiological adaptation.[39,40] Because subjective measures of sleepiness do not always accurately reflect the actual level of sleepiness-related impairment, objective measures of sleep such as wrist actigraphy are critical for the evaluation of both individual and unit-level readiness, especially in operational environments where performance is critical to mission success. Actigraphy has been shown to be a valuable tool to supplement fatigue risk-management systems for monitoring alertness in various high-risk and shift-work environments, including aviation,[41,42] trucking,[43] and hospitals.[44] More information about using tools such as actigraphy to implement good sleep hygiene practices is detailed below.

There is emerging evidence that military personnel may be especially susceptible to a unique constellation of symptoms comprising a newly proposed syndrome called trauma-associated sleep disorder.[45] This proposed syndrome is similar to, and could easily be confused with, rapid eye movement sleep behavior disorder because both are characterized by disinhibition of voluntary muscle movement during rapid eye movement sleep (resulting in the "acting out" of dream mentation). However, there are several critical differences that may affect prognosis and treatment, which are listed in Exhibit 26-2.

ROLE OF THE MILITARY MEDICAL OFFICER

The MMO plays a vital role in the education and training of unit leadership and personnel with regard to the importance of adequate sleep and the relationship between sleep and health. The US Army Performance Triad[46] recognizes that optimal readiness, health, and performance cannot be achieved without sufficient sleep, physical activity, and proper nutrition. MMOs should become familiar with this program and be prepared to assist service members to develop and achieve their sleep, activity, and nutrition goals.

Sleep is a primary physiological need, like hunger or thirst, but the "consumption" of sleep may be more heavily influenced by social and environmental factors than eating or drinking. Unit leaders and personnel often underestimate the amount of time needed for getting good quality, restorative sleep.

In military culture, sleep loss may be considered a sign of mental or physical toughness.[30] In fact, the opposite is true. MMOs must be prepared to educate unit personnel and leadership on the importance of adequate sleep to brain function and performance, and ultimately to the mission. This requires integration of good sleep hygiene practices into all relevant unit activities (eg, mission planning, work–rest cycles, shift scheduling).

Insufficient sleep threatens the mission in a number of ways. Failure to obtain adequate or restorative sleep can result in loss of energy, weariness, difficulty concentrating, and memory deficits.[47] Although service members sometimes endure periods of total sleep deprivation, chronic sleep restriction (insufficient daily sleep) is practically ubiquitous in deployed environments, which are characterized by adverse or constrained conditions.[48] Chronically sleep-restricted individuals may subjectively adapt to repeated or prolonged periods of sleep loss, but from an objective standpoint (ie, in terms of the effects of sleep loss on objectively measured performance), there is little evidence of adaptation. Figure 26-2 shows that chronic sleep restriction and total sleep deprivation both have qualitatively equivalent effects on performance; all that varies is the rate at which these deficits accrue. Even for elite service members who are highly trained and experienced, sleep loss results in significant decrements in vital cognitive abilities including vigilance, memory, and reasoning.[49] Basic guidance regarding the management of sleep and alertness is available in Army Techniques Publication 6-22.5, *A Leader's Guide to Soldier Health and Fitness*.[50]

Because sleep loss impacts a wide array of cognitive abilities and performance, it constitutes a significant threat to military personnel and operations. For example, sleep loss slows psychomotor responses and results in attentional lapses.[51] These lapses and slowed performance in some cases reflect microsleep—brief (0.5–15.0 s) intrusions of sleep into periods of wakefulness.[52] In fact, sleepiness-induced performance deficits (eg, lowered reaction time and impaired judgment) can occur even in the absence of microsleep. Microsleep episodes are sufficient but not necessary to produce sleepiness-related performance deficits. Duties performed by service members are often dangerous or conducted in dangerous environments. Lapses in performance and attention are not only safety concerns, they are also threats to mission success. Additionally, insufficient sleep results in poor decision-making, especially for decisions involving

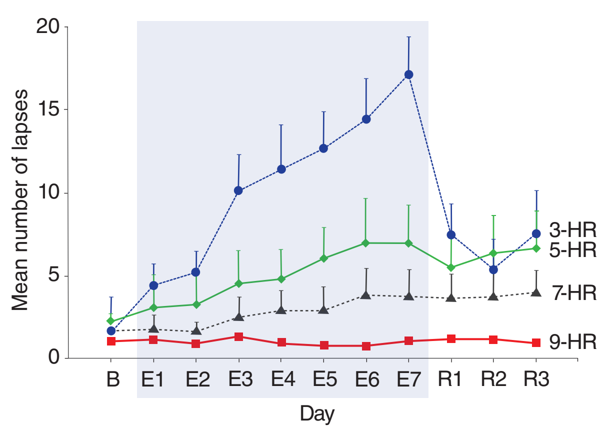

Figure 26-2. Mean number of lapses on the psychomotor vigilance task (and standard error) across days as a function of time in bed group.
B: baseline; E: experimental phase; R: recovery phase; HR: hours (time in bed)
Reproduced with permission from: Belenky G, Wesensten NJ, Thorne DR, et al. Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *J Sleep Res.* 2003;12(1):12.

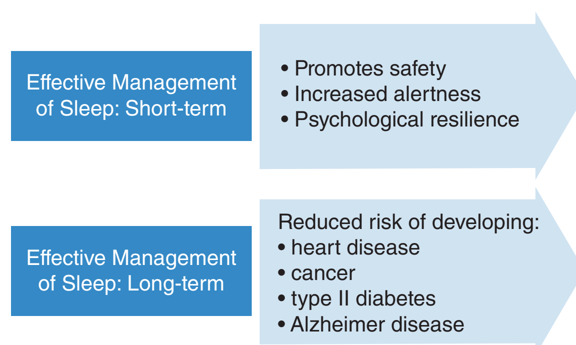

Figure 26-3. In the short term, effective management of sleep and alertness in the operational environment promotes safety,[1] military effectiveness,[2] and psychological resilience.[3] In the long term, a consistent regimen of adequate sleep may have multiple health benefits, including a relatively reduced risk of developing heart disease, cancer, type II diabetes, and Alzheimer disease.[4]

1. Thomas MJ, Ferguson SA. Prior sleep, prior wake, and crew performance during normal flight operations. *Aviat Space Environ Med*. 2010;81(7):665–670.
2. Wesensten NJ, Balkin TJ. The challenge of sleep management in military operations. *US Army Med Dep J*. 2013;Oct-Dec:109–118.
3. Germain A. Resilience and readiness through restorative sleep. *Sleep*. 2015;38(2):173–175.
4. Benedict C, Byberg L, Cedernaes J, et al. Self-reported sleep disturbance is associated with Alzheimer's disease risk in men. *Alzheimers Dement.* 2015;11(9):1090–1097.

risk-taking.[53] Leaders at all levels are expected to make decisions, sometimes with little time or information, and even small decrements in decision-making ability (speed or quality) can put missions and lives at risk.

Beyond its direct, short-term effects on mission accomplishment, sleep loss may have long-term deleterious effects on psychological resilience and the development of psychopathology.[54,55] Conversely, regularly obtaining adequate sleep may play a positive role in enhancing resilience (ie, the ability to recover from a stressful event or to grow in the face of adversity).[56] The military is concerned with training and equipping a ready and resilient force. MMOs play a key role in assuring that this goal is achieved by promoting healthy sleep.

Riding atop the circadian rhythm that mediates alertness or sleepiness across a 24-hour cycle, there are shorter, ultradian rhythms that mediate alertness on a much shorter, even moment-to-moment basis. In the short term, excessive subjective sleepiness can also be partially and momentarily masked by high motivation, excitement, exercise, and competing needs such as hunger or thirst. Also, it has been shown that sleep-deprived or restricted individuals will often become subjectively habituated to an increased sleep debt. Because those regions of the brain that are required for accurate self-assessment are impaired by sleep loss (eg, the prefrontal cortices), sleep-deprived or restricted individuals are functionally impaired and therefore poor judges of the extent to which they have been affected by insufficient sleep. For this reason, objective measures of sleep (eg, derived from wrist actigraphy) should be employed as part of a comprehensive alertness and sleep management program. Figure 26-3 gives more information about the positive effects of managing sleep in the short term and long term.

SLEEP HYGIENE AND FATIGUE MANAGEMENT TOOLS

Several tools and technologies can be applied to facilitate the management of sleep and alertness in the field, including hardware, such as wrist actigraphy (Figure 26-4) for objective measurement of sleep duration, continuity, and timing, and enabling software. Also, pharmaceuticals such as stimulants and hypnotics may be warranted under some circumstances. Independently, each of these tools can be used effectively to consolidate sleep or enhance alertness and performance during waking hours. Sleep can be consolidated by using hypnotic medications. Stimulants such as caffeine and nicotine can enhance alertness. Performance model-informed work–rest scheduling can be adapted to support both sleep requirements and the ability to be alert and well rested during duty hours.

Figure 26-4. Shown is the Actiwatch Spectrum, used for objectively measuring sleep.
Photograph courtesy of Philips Respironics, Bend, OR.

Optimum benefit can be realized when these tools are used in concert, as components of a comprehensive sleep–alertness management system. As described in Wesensten, Killgore, and Balkin,[57] an optimal system utilizes an objective measure of sleep–wake timing and duration for each individual operator rather than (*a*) estimates of the likely amount of sleep obtained based on the timing and duration of scheduled off-duty hours; or (*b*) unreliable self-reports of timing, duration, and quality of sleep. Currently, the best technology for measuring sleep timing, duration, and continuity in field environments is wrist actigraphy.

Wrist actigraphs are relatively unobtrusive, about the size and weight of a typical wristwatch. Some commercial models incorporate typical wristwatch functions. These devices use accelerometers to measure wrist movements—data from which sleep and wakefulness can be reliably determined and scored.[58] Sleep–wake scoring of wrist movement data is often performed by the devices in real time, and these data are stored in memory. A typical wrist actigraph can collect and store approximately 6 to 8 weeks of sleep–wake data, with the limiting factor being battery life. It is anticipated that even longer periods of continuous data collection will become available over the coming years, as advances in battery technology are made.

Several commercial products are currently marketed with claims they can be used to measure sleep–wake timing and duration. Many of these products are multifunction devices that provide a measure of daytime physical activity level in addition to an estimate of nighttime sleep, but they have not been adequately validated. Commercial wrist actigraphs that are designed and marketed for the sole purpose of measuring sleep–wake timing and duration have generally been tested against polysomnography (the gold standard for sleep–wake scoring) and found to be valid and reliable.

In the optimal, comprehensive sleep–alertness management system, objective (actigraphically derived) sleep–wake data serve as inputs into an individualized mathematical model (ie, a performance prediction algorithm that "learns" an individual's response to sleep loss and outputs a quantitative prediction of individual cognitive performance capacity). Thus, the mathematical model provides the means for interpreting the actigraph's sleep–wake data in terms of its meaningfulness for individuals in the operational environment, the likelihood of their making errors and having accidents,[59] and the rate at which they can perform useful mental work.[60] It also allows commanders and others to predict what further decrements in cognitive performance will occur if no sleep is allowed in the next X amount of hours and the benefits that would accrue if a nap of X hours were allowed at time Y.

The 2B-Alert Web application is an open-access, predictive tool designed to optimize cognitive performance by analyzing the effects of sleep–wake patterns, time of day, and caffeine consumption.[61] This tool was developed in an ongoing, collaborative project at the Walter Reed Army Institute of Research and the Biotechnology High Performance Computing Software Applications Institute (Frederick, MD). A mobile application using this technology can predict alertness and cognitive performance for individuals, and its functionality is expandable.[62] Using such scientifically validated tools that predict performance and recommend interventions during continuous and sustained operations will actually prevent decrements in performance from reaching critical thresholds.

When operationally feasible, reversal of sleep-loss-induced alertness and performance deficits is best accomplished with recovery sleep (either natural or pharmaceutically facilitated). Although stimulants can improve alertness and at least some aspects of cognitive performance,[63] it is important to keep in mind that they do not actually replace sleep; they only help delay its onset. Sleep debt continues to accrue during stimulant-sustained wakefulness, and in the absence of recovery sleep, escalating doses of stimulants are required to maintain alertness with increasing levels of sleep debt. The relative operational utility of stimulants and hypnotics are evaluated in the literature; operationally salient points include the following[57,64,65]:

- Equivalent doses of many stimulants such as d-amphetamine, modafinil, and caffeine have been established,[57] but because of its relative safety, efficacy, availability, and widespread use and acceptance, caffeine in the recommended doses should at this time be considered the stimulant of choice for use in operational environments.
- Sleep inducers can be used to effectively enhance sleep when the opportunity for sleep occurs during the daytime (when the circadian rhythm of alertness is in the ascending phase and therefore mitigates against sleep onset and maintenance).
    - Benzodiazepine agonists such as zolpidem are most effective for inducing and maintaining sleep, but "drug hangover effects" are possible and should be considered when these drugs are used in an operational environment.
    - Melatonin and synthetic melatonin receptor agonists (such as ramelteon) are generally less effective than benzodiazepine receptor agonists, but may be useful under some circumstances (eg, when the user has a significant sleep debt but still experiences difficulty sleeping during the daytime).

In addition to informing the command about sleep management and optimization, MMOs must make decisions about the use of alertness-enhancing pharmaceuticals. It is imperative that MMOs know the effectiveness and possible side effects and hangover effects of these products and prescribe them accordingly.

GUIDANCE TO THE COMMANDING OFFICER

In military environments, the extent to which stress exposure impacts psychological functioning and military effectiveness is dependent in part on the quality of the unit leadership.[66] Chronic sleep restriction is among the most salient stressors faced by military personnel. Unit leadership plays a key role in ensuring all unit members get enough sleep. In addition to its benefits for health and well-being, adequate sleep is a personnel readiness issue and is just as important as weapon or equipment readiness. Leaders set the operational tempo for their unit, and that pace should be set to maximize individual and unit performance. Optimal performance can be achieved only when service members obtain adequate sleep. In the current conflicts, mental agility or "cognitive fitness" is essential for success. Sleep is a vital component of cognitive fitness. Commanders are urged to make sleep a priority for themselves and for their troops. Sleep should be considered an item of logistical resupply just like food, water, fuel, and ammunition, and should be addressed when planning missions.

SUMMARY

Sleep and rest, or "time off task," provide qualitatively and physiologically distinct benefits to the soldier. In the short term, effective management of sleep in the operational environment promotes safety, military effectiveness, and resilience. In the long term, evidence is emerging that adequate sleep results in multiple health benefits later in life. Therefore, the goal should always be to maximize sleep quality and duration to the extent possible given operational realities and exigencies. This goal can best be achieved by implementing a comprehensive sleep–alertness management system that includes hardware such as wrist actigraphy (for objective measurement of sleep duration, continuity, and timing); software that provides performance predictions and guidance regarding sleep–wake interventions; and an armamentarium of pharmaceuticals (eg, caffeine) and hypnotics (eg, zolpidem) to optimize short-term control over alertness and sleep as needed.

SLEEP MANAGEMENT RESOURCES

The links below provide further details about the US military's guidance on sleep for service members at all levels. They detail functional sleep management tools that can help ensure individual service member health and performance as well as unit operational effectiveness.

- 2B-Alert App –web-based demo (https://2b-alert-web.bhsai.org/2b-alert-web/login.xhtml)
- 2B-Alert App – description (https://techlinkcenter.org/technologies/2b-alert-personalized-alertness-cognitive-performance-app/)
- US Army Performance Triad website (https://p3.amedd.army.mil/)
- US Army Medicine's Performance Triad training sessions for soldiers and leaders (http://www.armymedicine.mil/Pages/Performance-Triad-Training-Sessions.aspx)
- Army Techniques Publication 6-22.5, *A Leader's Guide to Soldier Health and Fitness* (http://www.apd.army.mil/epubs/DR_pubs/DR_a/pdf/web/atp6_22x5.pdf)

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