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Sleep physiology, pathophysiology, and sleep hygiene

Navya Baranwal [a,b], Phoebe K. Yu [a], Noah S. Siegel [a,*]

[a] Massachusetts Eye & Ear, Department of Otolaryngology, Boston, MA, United States of America
[b] The Warren Alpert Medical School of Brown University, Providence, RI, United States of America

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ABSTRACT

Despite sleep's fundamental role in maintaining and improving physical and mental health, many people get less than the recommended amount of sleep or suffer from sleeping disorders. This review highlights sleep's instrumental biological functions, various sleep problems, and sleep hygiene and lifestyle interventions that can help improve sleep quality. Quality sleep allows for improved cardiovascular health, mental health, cognition, memory consolidation, immunity, reproductive health, and hormone regulation. Sleep disorders, such as insomnia, sleep apnea, and circadian-rhythm-disorders, or disrupted sleep from lifestyle choices, environmental conditions, or other medical issues can lead to significant morbidity and can contribute to or exacerbate medical and psychiatric conditions. The best treatment for long-term sleep improvement is proper sleep hygiene through behavior and sleep habit modification. Recommendations to improve sleep include achieving 7 to 9 h of sleep, maintaining a consistent sleep/wake schedule, a regular bedtime routine, engaging in regular exercise, and adopting a contemplative practice. In addition, avoiding many substances late in the day can help improve sleep. Caffeine, alcohol, heavy meals, and light exposure later in the day are associated with fragmented poor-quality sleep. These sleep hygiene practices can promote better quality and duration of sleep, with corresponding health benefits.

Contents

Abbreviations: CNS, central nervous system; CSA, central sleep apnea; CV, cardiovascular; DM, diabetes mellitus; EEG, electroencephalogram; GERD, gastroesophageal reflux disease; NREM, non-rapid eye movement; OSA, Obstructive sleep apnea; REM, rapid eye movement; US, United States.

* Corresponding author at: 243 Charles St, Boston, MA 02114, United States of America.
E-mail address: noah_siegel@meei.harvard.edu (N.S. Siegel).

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Sleep is fundamental to optimal physical and mental health. Both sleep quantity and sleep quality are essential for nearly every body system, and suboptimal sleep impacts cardiovascular (CV) health, mental health, cognition, memory consolidation, immunity, reproductive health, and hormone regulation. Despite this, many individuals are not achieving adequate quantity or quality of sleep. More than one-third of the United States (US) population gets less than ideal sleep, and between 50 and 70 million US adults have various sleep disorders.[1,2] Intrinsic sleep disorders, such as insomnia, sleep apnea, and circadian-rhythm-disorders as well as poor sleep hygiene can lead to significant morbidity and contribute to or exacerbate a variety of medical and psychiatric conditions. In addition to treating coexistent intrinsic sleep disorders, the best treatment for long-term sleep improvement is optimal sleep hygiene, defined as behavioral and lifestyle interventions that can promote better sleep. This review highlights basic sleep physiology with its impact on essential biologic functions, discusses common sleep disorders, and makes recommendations for optimal sleep hygiene.

Physiology of sleep

Sleep and wake states are generated by intrinsic neural networks and regulated by circadian mechanisms. The initiation and maintenance of sleep requires the suppression of ascending arousal systems that promote wakefulness. Extracellular adenosine increases throughout the awake period, and rising levels signal shifts toward sleep. The adenosine activates inhibitory neurons of the ventrolateral pre-optic area of the brain and serves as a sleep switch.[3]

Intrinsic biologic clocks control various homeostatic functions in the body, including sleep and wake cycles. These circadian clocks follow rhythms, which are endogenously driven physiological oscillations, and have a cycle length of approximately 24 h. The central circadian clock is called the suprachiasmatic nuclei and is located within the hypothalamus. Circadian rhythms influence behavioral and physiological functions such as eating, drinking, body temperature, neurohormone secretion, and sleep-wakefulness via feedback loops and molecular markers.[4–6]

In addition to endogenous cycling of transcriptional and translational signals, the circadian rhythm is influenced by external factors, known as “zeitgebers”. These include light and dark exposures as well as social cues. Light signals are picked up in the retina which sends electrical impulses to the brain, indicating it is daytime. Lack of light exposure is also perceived through the retina. In low light situations, melatonin is secreted by the pineal gland.[5,7] Melatonin, often referred to as the ‘hormone of darkness’, rises in the evening and peaks in the early morning.[8] It has direct effects on sleep regulatory mechanism. Similarly, cortisol, another stimulatory hormone, rises in response to light exposure in the morning.

Sleep architecture

A good night's sleep is characterized by a rhythmic, cyclic process that alternates between three stages of non-rapid eye movement (NREM) sleep and a fourth stage of rapid eye movement (REM) sleep (Fig. 1).[4,9] This is known as sleep architecture. When sleep architecture is disrupted, individuals do not realize the full restorative benefits of sleep. As will be reviewed, many factors can negatively impact sleep architecture. Those factors include sleep quantity, light exposure, caffeine, noise exposure, alcohol and many more.

Good sleep architecture in a night's sleep includes 4–5 sleep cycles. Each sleep cycle is approximately 90 min in duration, includes light and deep sleep, and is punctuated by an episode of REM sleep. Each stage has unique roles in maintaining the brain's cognitive functions

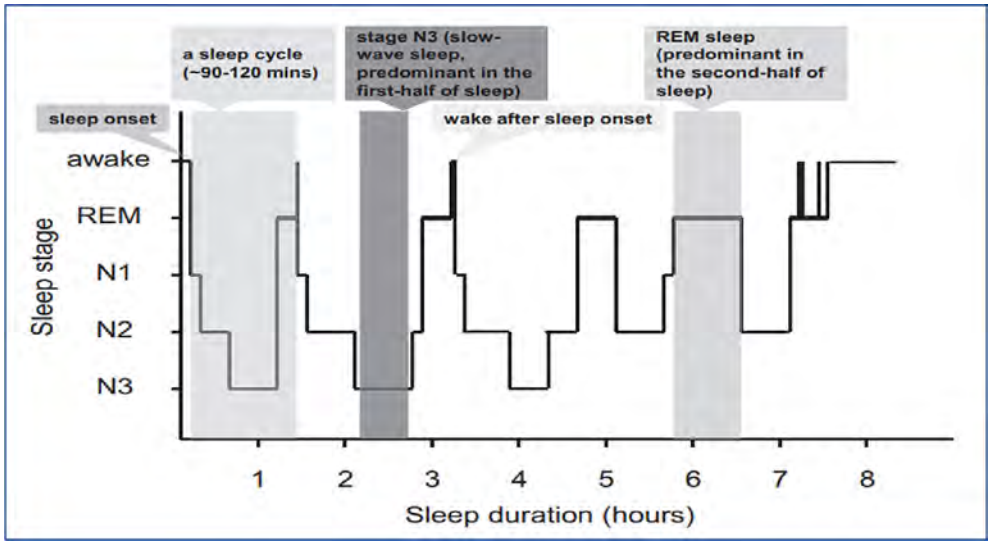

Fig. 1. Stages of sleep. Sleep is divided into four stages, including: (1) N1, a stage of falling asleep/light sleep; (2) N2, during which time heart rate slows and body temperature decreases; N3, or slow-wave sleep (SWS), which is a stage of deep sleep and body repair; and (4) rapid-eye movement (REM) sleep, during which time dreaming occurs as well as skeletal muscle atonia. Slow wave sleep predominates in the early hours of sleep and REM sleep becomes more dominant in the later hours of sleep. (Reproduced from Tan et al.)[9]

and repairing the body. However, it is believed that it is the interplay of each sleep stage as well as the number of sleep cycles that leads to the best sleep.

Stage 1 is a light sleep that occurs when one's eyes are closed, and arousal is quite easy. It is often considered the 'entry' to sleep and generally comprises approximately 5% of a full night's sleep. Stage 2 is slightly deeper sleep that occurs when the eyes stop moving, heart rate slows, and body temperature lowers. Stage 2 sleep occupies about 50% of a night's sleep and is characterized by sleep spindles and k complexes on electroencephalogram (EEG) tracings. The exact function of these EEG patterns are unclear but are likely associated with memory consolidation. Stage 3 sleep, also known as deep sleep, slow wave or delta sleep is characterized by high amplitude slow waves and predominates in the first half of the night. Normally, it should occupy 20–25% of the night. Deep sleep is often considered the stage of sleep where the body does much of its nocturnal repair work and strengthening of the immune system. It is often difficult to awaken a person in deep sleep and the amount of deep sleep often decreases in older individuals.

REM sleep occurs after stage 3 and is characterized by rapid eye movements and skeletal muscle atonia. It predominates during the second half of the night and occupies approximately 20% of a normal night's sleep. We dream during REM sleep, and it is believed that much of memory consolidation takes place during REM sleep. Heart and respiratory rates often quicken and become less regular during REM sleep. REM cycles are often longer as the night progresses.[3] Individuals with sleep disorders such as obstructive sleep apnea may not achieve adequate amount of REM sleep.

Biological effects of impaired sleep

Sleep plays several fundamental biological functions in our bodies, allowing for maintenance, repair, and building of the body (Fig. 2). Both sleep quantity and sleep quality combine sleep to provide health benefits, and can improve mood, cognitive performance, and growth and development. While sleep impacts every body system, below we focus on the specific impacts of sleep on the neurologic system, immune system, CV system, and the endocrine system (Table 1).

Hormonal regulation and metabolic function

Exposure to acute sleep restriction in the acute setting induces the presence of insulin resistance[10–12] Poor sleep, in the form of short sleep, long sleep, insomnia, and sleep-disordered breathing are all associated with an increased propensity to insulin resistance and risk of developing diabetes mellitus (DM).[13] As summarized by Reutrakul and Van Cauter, there are multiple mechanistic pathways by which impaired sleep can increase DM risk (Fig. 3).[14]

Several hormones have a circadian rhythm and are altered by poor quality sleep, irregular sleep schedules and intrinsic sleep disorders. For instance, cortisol rises in the early part of the day and is important for dealing with somatic stresses. Growth hormone also has a circadian pattern and is primarily secreted during deep sleep. Impaired sleep or limited deep sleep has the potential to impact growth and muscle repair. Sleep also influences the pituitary-gonadal axis, and sleep disorders can lead to central suppression of testosterone, manifesting as sexual dysfunction or decreased libido.[15]

Fragmented sleep results in an alternation in the normal balance of ghrelin and leptin, two hormones which promote hunger and satiety, respectively.[16] When these hormones are unbalanced, an individual often has increased hunger and appetite and an impaired sense of satiety, increasing the risk of obesity and DM.[17] Poor sleep has also been associated with an increased risk for unhealthy eating patterns, which can secondarily lead to adverse health outcomes.[18–20] A recent study has shown how this might occur on an experimental basis.[21] Using a randomized controlled crossover design, 12 healthy individuals were subjected to periods of four versus nine hour sleep opportunities.

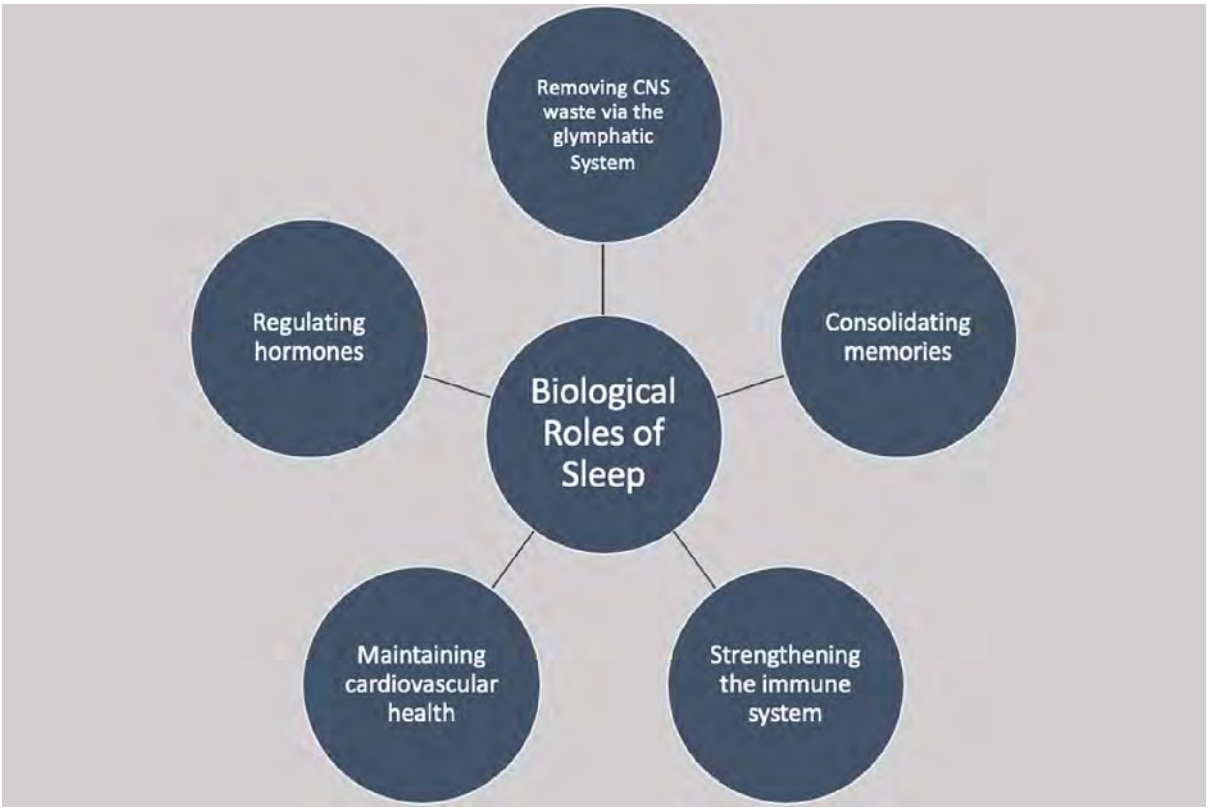

Fig. 2. Health benefits of sleep. Sleep provides basic biological functions as shown.

Table 1
Impact of impaired sleep quality or quantity.

Metabolic
• Insulin resistance and increased diabetes risk
• Impairment in growth hormone and muscle repair
• Testosterone suppression and decreased libido
• Ghrelin/leptin imbalance and increased appetite
Cardiovascular
• Increase in autonomic arousal
• Hypertension
• Increased risk for arrhythmia
• Endothelial dysfunction
• Increased risk for cardiovascular events
Immune
• Reduction in antibody production
• Inflammatory cytokine production
• Increased cold and infection susceptibility
Neurologic
• Glymphatic system impairment
• Memory consolidation impairment
Psychological
• Increased depression risk
• Acute effects on mood, irritability, energy level, sense of well-being

During the sleep restriction periods, the individuals had a significant increase in their daily energy intake, body weight, and accumulation of visceral fat (Fig. 4).

CV system

Sleep quality has a substantial impact on the cardiovascular system. During normal sleep, heart rate slows, blood pressure dips, and the autonomic balance shifts from sympathetic tone toward more parasympathetic tone. This resting of the cardiovascular system appears to be essential for optimal CV health. Increased autonomic activity stresses the cardiovascular system and increases the risk of adverse CV outcomes. There is substantial data indicating a relationship between inadequate sleep and hypertension.[22–25] and poor sleep and the development of endothelial dysfunction.[26] In addition, there is increasing data that links poor sleep to an increased risk for developing cardiac arrythmias. For example, 403,187 participants in the UK Biobank were assessed for a healthy sleep pattern according to five parameters: sleep duration, chronotype, insomnia, snoring, and daytime sleepiness.[27] A healthy sleep pattern was associated with a lower risk of atrial fibrillation and bradyarrhythmia (but not ventricular arrhythmias), independent of traditional risk factors (Fig. 5).

Given these associations, it is not surprising that poor sleep has been linked to a higher risk of coronary artery disease, stroke, and myocardial infarction.[28,29] Substantial epidemiological data suggest that the relationship between sleep duration and cardiovascular events, as well as sleep and overall mortality is J-shaped, with both short sleep <6 h and long sleep >9 h being associated with an increased risk of CV death and all-cause mortality according to meta-analytic studies.[30,31] This includes the results of a large meta-regression analysis of 40 prospective cohort studies, encompassing 2,200,425 participants (Fig. 6).[31]

In individuals with obstructive sleep apnea, repetitive respiratory events characterized by hypoxemia, blood pressure spikes, heart rate acceleration, and autonomic arousal particularly raise the risk for hypertension, unstable cardiac rhythms as well as ischemic CV events.

Immune system

Sleep and the immune system are closely connected, and the relationship between the two is bidirectional. Sickness can impact sleep, by either disrupting sleep or increasing sleep duration or intensity, and sleep itself strengthens the immune system.[32] Sleep loss and disturbance has been shown to reduce natural killer cell activity and antibody production, increasing the risk of infections and possibly even cancers. Sleep loss also generates inflammatory cytokines, increasing the risk for cardiovascular and chronic metabolic disorders.[32] One study found that people with insomnia have fewer post-influenza vaccine antibodies

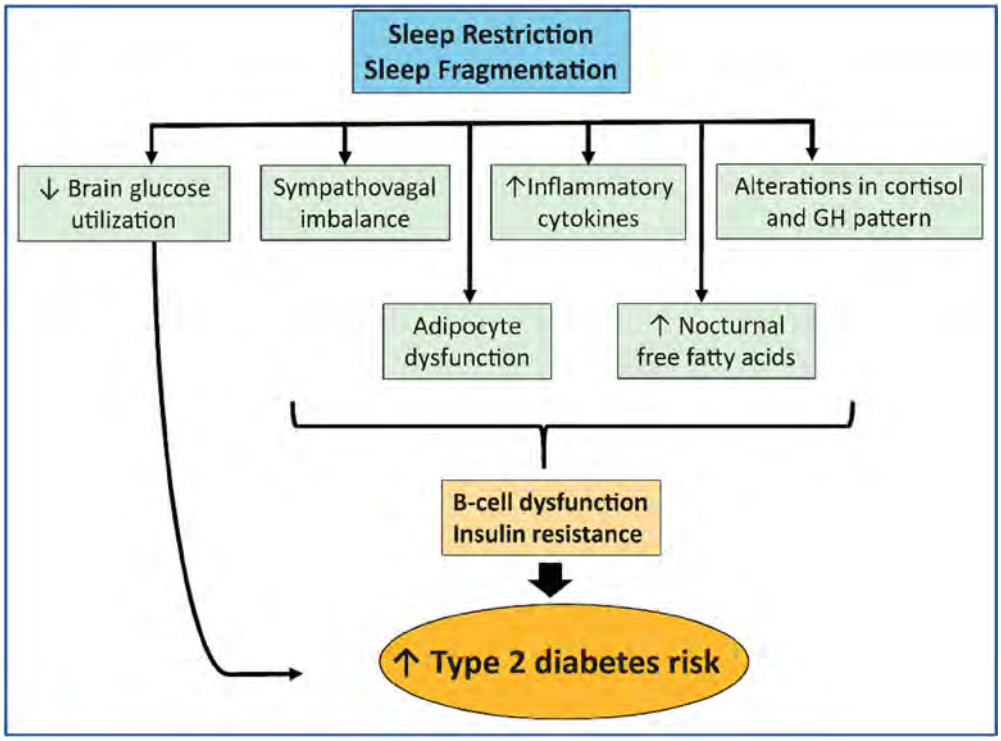

Fig. 3. Sleep influences upon diabetes risk. Mechanisms by which sleep restriction and sleep fragmentation may increase the risk for type 2 diabetes. (Reproduced from Reutrakul et al.)[14]

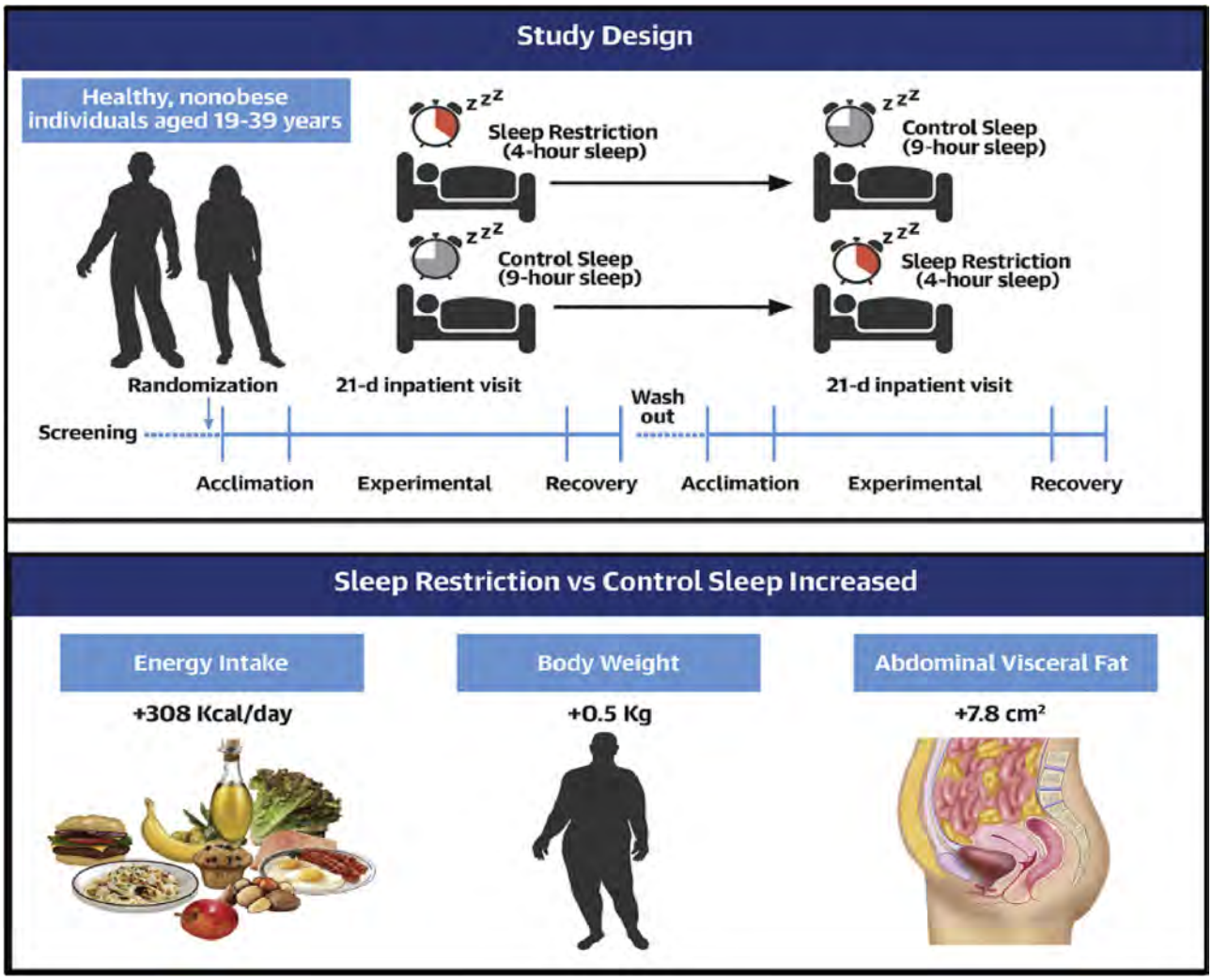

Fig. 4. Impact of restricted sleep on energy intake and weight gain. The top panel shows the study design, which involved a randomized crossover study of 12 individuals, who alternated between a period of sleep restriction (4 h of sleep) versus control (9 h sleep opportunity).
The bottom panel shows the effects of sleep restriction, which included increase in energy intake, body weight, and abdominal visceral fat in response to sleep restriction. (Reproduced from Covassin et al.)[21]

compared to people who have healthy sleep.[33] Another study found that sleeping <5 h duration was associated with an increased susceptibility (OR: 4.50, 95% CI: 1.08–18.69) to the common cold compared sleeping >7 h per night.[34] A few studies have suggested a potential link between poor sleep and cancer risk, but present data are not conclusive.

Sleep and brain function

There is an increasing interest in the potential relationship between chronically poor sleep and brain health. During wakefulness, we accumulate waste products in our brains that are likely associated with the sensation of feeling tired or less focused as we remain awake. First

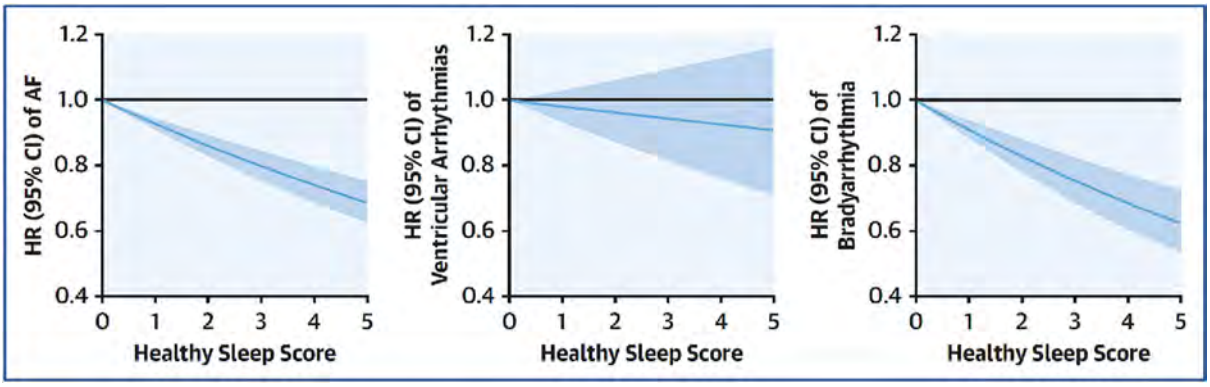

Fig. 5. Sleep and arrhythmia risk. Adjusted hazard ratios for atrial fibrillation, ventricular arrhythmias, and bradyarrhythmia according to healthy sleep score (ranging from 0 = poorest sleep pattern to 5 = healthy) among 403,187 participants in the UK Biobank study. (Reproduced from Li et al.)[27]

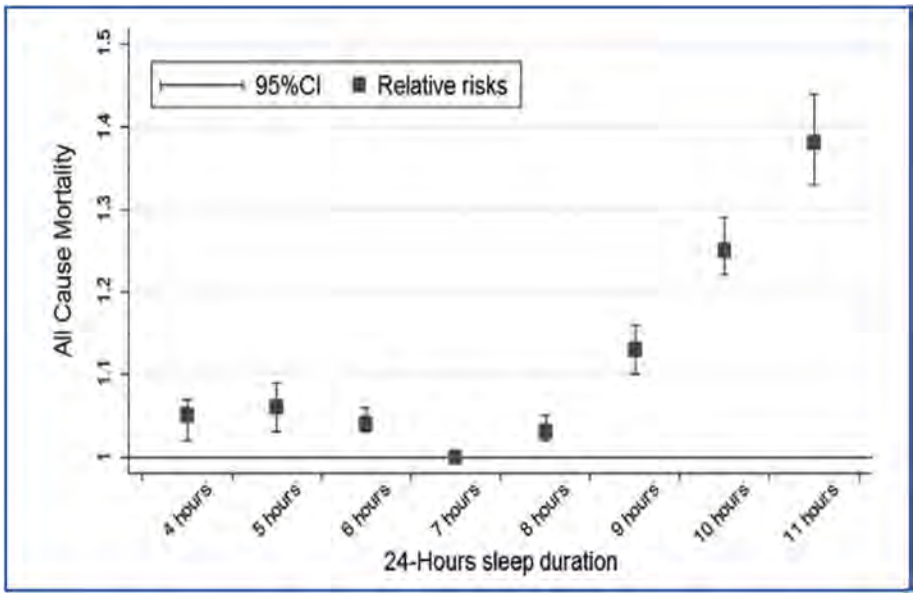

Fig. 6. Relationship between sleep duration and all-cause mortality. Shown are the hazard ratios for all-cause mortality according to sleep hours, with 7 h of sleep as the reference. (Reproduced from Liu et al.)[31]

described at the University of Rochester in 2012, the glymphatic system is a system of perivascular channels important for removal of these accumulated waste products during sleep.[35] The glymphatic vasculature is formed by astroglial cells whose "feet" surround the spaces around brain capillaries. When cerebrospinal fluid is forced out of arteries and into the perivascular spaces, elimination of soluble proteins, metabolites, and potentially neurotoxic waste products such as amyloid occurs through channels on the astroglial cells.[36] The glymphatic system may also help distribute non-waste compounds, including glucose, lipids, amino acids, and neurotransmitters, in the brain.[37]

Increased glymphatic function during sleep is likely due to decreased levels of norepinephrine during natural sleep (or states of anesthesia-induced low norepinephrine tone), leading to an expansion of the brain's extracellular space and decreased resistance to fluid flow (Fig. 7).[35,37,38] It is believed that sleep disruption can lead to decrease in function of the glymphatic system. As a result, waste accumulation in the CNS has been postulated as a potential contributor to various neurodegenerative conditions, including Alzheimer's and other dementias caused by protein aggregation.[39] While more study of pathophysiological pathways is indicated, clinically, an association between sleep deficiency and dementia risk has been noted in two large studies.[40,41]

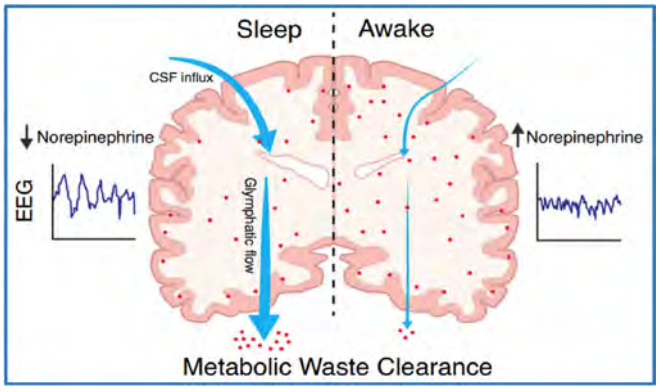

Fig. 7. Sleep and the glymphatic system. During nonrapid eye movement sleep or anesthesia-induced states of low norepinephrine tone, cerebrospinal fluid enters the brain, intermixes with interstitial fluid, and clears its of waste products. During wakefulness or states of high norepinephrine flow, influx of cerebrospinal fluid to the brain decreases. (Reproduced from Hauglund et al).[38]

Memory consolidation

While knowledge acquisition and recall occur only during wakefulness, sleep is critical for memory consolidation, the process of stabilizing memories and consolidating learned content into long-term storage. Furthermore, there appears to be a filtering process where memories that are unimportant are not consolidated. Neuronal replays of representations from the hippocampus lead to the gradual transformation and integration of representations into neocortical networks (systemic consolidation) during stage 3 NREM sleep. Brain oscillations during REM sleep stabilize the transformed memories by upregulating local synaptic plasticity (synaptic consolidation).[42] Thus, sleep not only strengthens memory but can also enable the formation of new associations, thus allowing people to form novel inferences and insights.[43]

Sleep and psychological well-being

There exists a bidirectional relationship between sleep and psychological well-being. For example, people with depression can have insomnia, reduced slow wave sleep, and a disinhibition of REM sleep.[44] On the other hand, insomnia and sleep problems can also serve as independent risk factors for depression as well.[44,45] Insomnia and poor sleep patterns can also increase the risk of anxiety, addictive disorders, and poor mental health.[45–47] On an acute basis, poor sleep can lead to decreased mood, irritability, fatigue, and difficulty concentrating.

Sleep disorders

Many individuals suffer from intrinsic sleep disorders resulting in significant morbidity. Sleep disorders are also associated with high rates of impaired daytime functioning, poor occupational performance, motor vehicle accidents, and heightened pain perception.[48,49] This section provides an overview of the most common sleep disorders.

Insomnia is a common condition which is characterized by difficulty falling asleep, staying asleep, or both and is associated with daytime impairment. It has an over 10% prevalence in the adult population and results in substantial impact on wellbeing, mood, relationships, and

productivity.[50] Insomnia may exist in isolation or may be associated with other conditions or exposures. Insomnia is often linked to stress, environmental conditions such as noise, light, temperature as well as jet lag and shift work. Furthermore, insomnia often coexists with depression, anxiety, pain, sleep apnea, restless leg syndrome, dementia, endocrine disorders, pain, and certain medications. Symptoms of insomnia include sleepiness during the day, fatigue, grumpiness, and problems with concentration or memory.[51]

Obstructive sleep apnea (OSA) is a condition characterized by repetitive obstruction or narrowing of the upper airway during sleep. Globally, nearly 1 billion adults have OSA.[52] The causes of OSA include anatomic abnormalities such as obesity or tonsillar hypertrophy and individual endotypes which may predispose an individual to nocturnal airway obstruction. Furthermore, sleep related muscle relaxation and the impact of gravity on a horizontally oriented airway will further exacerbate upper airway obstruction. With each respiratory event, the airway narrows, oxygen levels often dip, and arousals undermine normal sleep architecture. Repetitive respiratory events are associated with high blood pressure, heart attack, and stroke.[53] Sleep apnea is most often treated with positive airway pressure therapy. Other treatment options include surgical therapy, weight loss, oral appliance therapy, and hypoglossal nerve stimulation. Central sleep apnea (CSA) is a form of sleep apnea characterized by lack of airflow without effort. CSA can be caused by a central/brainstem condition, narcotic medications, high altitude, or CV disease such as congestive heart failure.[53]

Circadian rhythm disorders occur when an individual's internal clock is not aligned properly with the external light-dark cycle. One example is delayed sleep phase syndrome, which is often seen in adolescents and characterized by late bedtimes and difficulty awakening in the AM, commonly for school. Shift work disorder occurs in people who work at night and have difficulty sleeping during the daytime.[54] The symptoms of circadian rhythm disorders include alternating insomnia and hypersomnia, emotional disturbances, and gastrointestinal distress. Certain pharmacologic treatments such as melatonin as well as timed light exposure can help resynchronize the internal circadian clock with the light-dark cycle and reduce symptoms.[55]

Other sleep disorders include narcolepsy, hypersomnia, sleep-related movement disorders, and parasomnias.[51] Certain medications, such as decongestants, antihistamines, beta blockers, steroids, and selective serotonin reuptake inhibitors; and medical issues, including pain conditions, gastroesophageal reflux disease (GERD), stress and anxiety, urologic issues, respiratory conditions, and neurological conditions, can also delay sleep onset and/or lead to poor sleep quality.[56–60]

In addition to these sleep disorders, individuals may suffer from an adverse lifestyle pattern in which they voluntarily restrict sleep time to levels below what is recommended. This behavioral pattern has been termed behaviorally induced insufficient sleep syndrome.

Screening and diagnosis of sleep disorders

Screening for sleep disorders can occur through a variety of methods. Validated questionnaires have been created to aid in screening for sleep disorders, including the Pittsburgh Sleep Quality Index to assess sleep quality,[61] the Epworth sleepiness scale for daytime sleepiness,[62] the STOP-BANG for undiagnosed obstructive sleep apnea,[63] and the PSQ-SRDB for pediatric sleep-disordered breathing.[64] Reported symptoms like inability to fall asleep, excessive daytime sleepiness, snoring, gasping or choking during sleep, or the presence of medical comorbidities like atrial fibrillation or hypertension can prompt further diagnostic testing. The mainstay for diagnosis of OSA and other sleep disorders is through polysomnography, a study in which the patient sleeps while physiologic variables, including brain waves, oxygen levels, heart rate, breathing, and eye and leg movements, are recorded. There are a multitude of other screening and diagnostic tests for sleep disorders, including actigraphy and sleep latency testing, as well as newer wearable and home devices; a full discussion of these tests are beyond the scope of this article.

Sleep hygiene and lifestyle interventions

In addition to sleep disorders and medical issues, daily behaviors, routines, and environmental exposure pertaining to noise, temperature, sleep surface, and light exposure play an important role in sleep. For various sleep problems, using sleeping pills and self-medicating with alcohol to induce sleep has been ubiquitous in our society. While soporific agents such as benzodiazepines, antihistamines, alcohol and barbiturates may help with sedation, they are associated with adverse outcomes, including increased physical and mental dependence, non-physiologic sleep, daytime sedation, behavioral side effects, increased risk for falls particularly in the elderly population, and increased mortality.[65] These authors do not endorse the use of sleeping pills unless in specific circumstances as prescribed by a physician. However, low dose of melatonin, a naturally occurring hormone, has a relatively benign side-effect profile and has been shown to modestly decrease sleep onset latency, increase total sleep time, and improve sleep quality.[66] The best treatment for long term improvement of sleep is behavior modification to include healthy sleep-promoting routines. Sleep hygiene refers to behavioral and lifestyle interventions around sleep time and throughout the day that positively influence sleep quality and duration. This section will review common sleep hygiene and lifestyle interventions that may impact sleep (see Table 2).

Sleep duration

People should aim to sleep between 7 and 9 h of sleep.[67] Sleeping <7 h is associated with adverse health outcomes, impaired immunity, impaired performance, increased errors, and greater risk of accidents. Some studies show that sleeping >9 h is also associated with health risk, although it might be appropriate for young adults or some individuals with illnesses.[68]

Consistent sleep schedule

Going to sleep and waking up at the same time each day, including on weekends and during travel, is perhaps the most important aspect of sleep hygiene. A regular sleep schedule helps maintain the body's internal clocks, reduces daytime sleepiness, and allows people to fall asleep and wake up more easily.[69,70] Furthermore, aligning with our bodies internal circadian rhythms helps optimize our mental health, endocrine system, and reproductive system.

The importance of sleep regularity is emphasized by a recent study of 1992 participants in the Multi-Ethnic Study of Atherosclerosis who were followed for a median of 4.9 years after undergoing 7-day wrist actigraphy to assess sleep regularity.[71] Those individuals with more

Table 2
Sleep hygiene tips.

Sleep hygiene tips
• Aim to get between 7 and 9 h of sleep
• Have a consistent sleep time
• Exercise regularly
• Avoid late afternoon/evening naps and long naps
• Avoid light exposure (electronics, etc.) near bedtime
• Limit caffeine consumption in the afternoon/evening
• Limit alcohol assumption
• Avoid large mixed meals and unhealthy foods near bedtime
• Practice mindfulness techniques
• Create a dark, cool, and quiet sleeping environment
• Have a constant bedtime routine
• Refrain from using the bed for non-sleep activities
• Use comfortable mattress, pillow, and bedding

frequent alteration in either sleep duration or sleep timing had a higher frequency of non-fatal or fatal cardiovascular events during follow-up (Fig. 8).

Exercise

The physical and mental benefits of consistent physical activity are well known, including improvements to sleep quality.[72] The American Heart Association recommends fitting in at least 150 min per week of moderate-intensity aerobic activity or 75 min per week of vigorous aerobic activity (or some combination of both).[73] A 30 min session of moderate aerobic exercise can help boost sleep quality in that night. The National Sleep Foundation encourages people to exercise without any restriction for the time of day as long as it is not at the expense of sleep duration.[72] While the exact mechanism of how physical activity improves sleep is unclear, studies have shown that moderate aerobic exercise increases the amount of deep sleep as well as sleep duration. Exercise has also been shown to reduce pre-sleep anxiety and improve sleep in patients with chronic primary insomnia.[74] In addition, there is growing appreciation for other probable mechanisms by which physical activity and exercise can influence sleep physiology, and conversely how sleep quality may influence physical performance and muscle recovery, as summarized by Chennaoui et al. (see Fig. 9).[72]

Weight loss

Losing weight or maintaining an optimal body weight can help improve sleep.[75] For example, weight loss has been shown to greatly improve sleep-disordered breathing in patients with OSA, improving sleep architecture and decreasing daytime sleepiness.[76] Surgical weight loss through bariatric surgery reduces the apnea hypopnea index for patients with OSA but may not cure it completely, and continued OSA treatment will likely be needed. Results are better in younger patients with lower body-mass index.[77] Furthermore, overweight individuals are more likely to suffer from GERD. The presence of GERD often results in nocturnal arousals, chest discomfort, and a need to sleep in a more upright position.

Napping

Most sleep experts believe that a single consolidated period of sleep for 7–9 h each day during darkness on a regular schedule is optimal. However, more research is emerging that napping can provide substantial health benefits such as relaxation, reduced fatigue, and improved mood and alertness.[78] However, there are potential ramifications of napping. Generally speaking, when a nap is to be considered, a 20–30 min nap in the early afternoon is often most appropriate. Longer naps may lead to grogginess or disorientation upon awakening if an individual enters deep sleep. For younger individuals, a mid-day nap has been shown to be beneficial while for older populations, excessive napping may be linked with negative outcomes.[79] If an individual suffers from insomnia, naps are not advisable as they may result in more difficulty initiating sleep at the desired bedtime.

Light exposure

As discussed above, light exposure sends an alerting signal to the brain through diminished secretion of melatonin. Reducing both ambient light exposure and light from electronic devices promotes earlier sleep onset and improves sleep quality. Even low levels of light from phones or e-Book devices can delay sleep and impair alertness the next morning.[5] Approaches to reduce light exposure late in the day include avoiding screens, darkened room, blue light blocking glasses, or wearing a sleeping mask. The effectiveness of blue light filters is not conclusive and stimulation from screens may still affect sleep.[80,81]

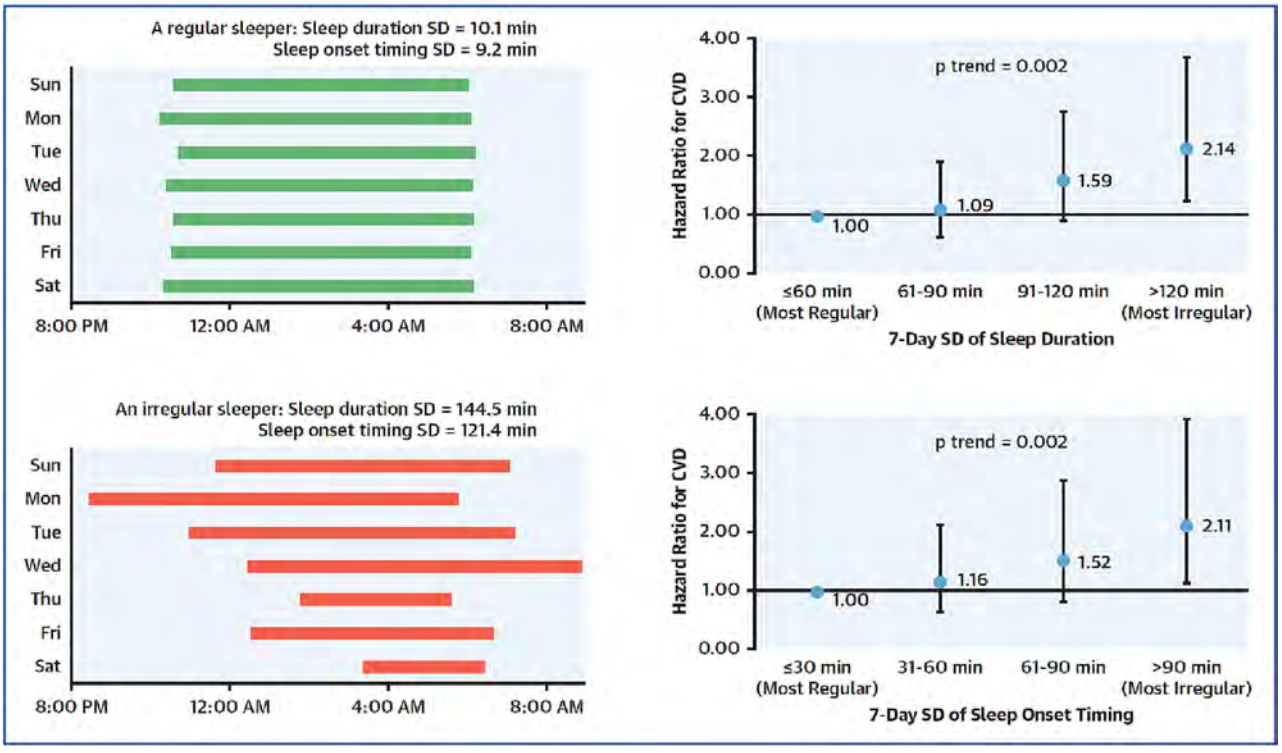

Fig. 8. Regularity of sleep patterns and cardiovascular risk. The left panels show two examples from the 7-day sleep patterns obtained by Huang et al. in their study of 1992 individuals using wrist actigraphy. Shown is the sleep pattern for a regular sleeper (top left) and irregular sleeper (bottom left). The top right panel show the relationship between the 7-day standard deviation (SD) of sleep duration and hazard ratio for cardiovascular disease (CVD). The bottom right panel shows the 7-day standard deviations for sleep onset timing and CVD risk. (Reproduced from Huang et al.)[71]

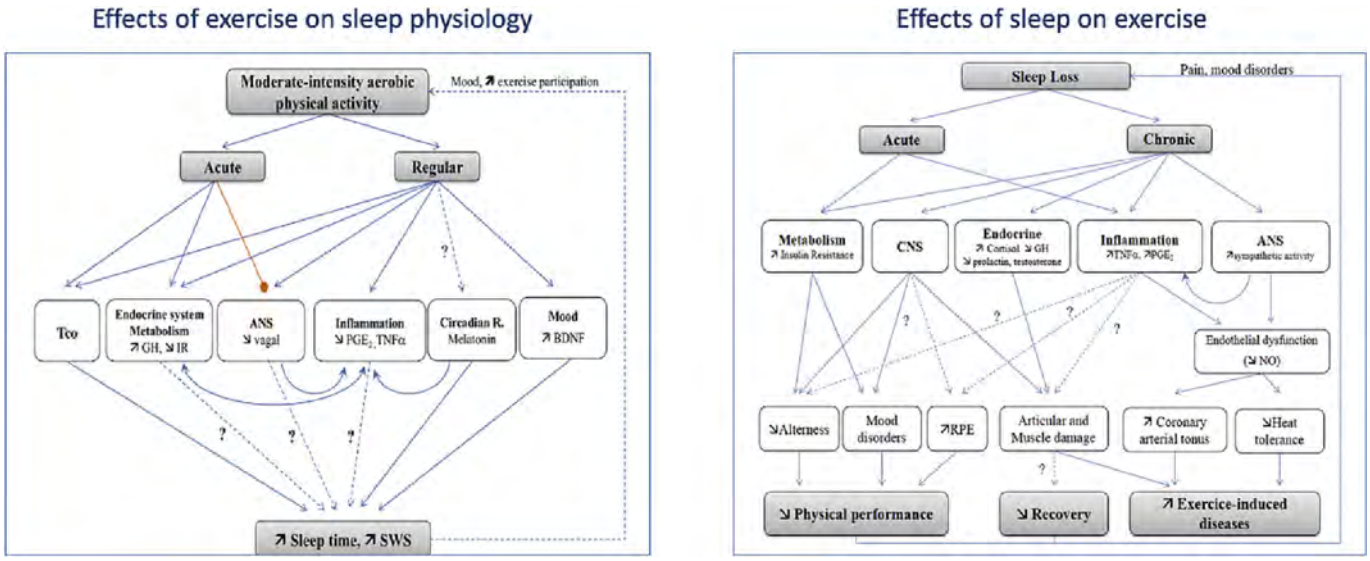

Fig. 9. Reciprocal relationship between exercise and sleep physiology. The left panel illustrates possible pathways by which acute or regular exercise may affect sleep, including potential effects on the autonomic nervous (ANS), brain-derived neurotrophic factor (BDNF), circadian rhythm (Circadian R), growth hormone (GH), insulin resistance (IR), prostaglandin E2 (PGE2), slow wave sleep (SWS), body core temperature (Tco), and tumor necrosis factor alpha (TNF-a). The right panel illustrates possible effects of acute or chronic sleep deprivation/sleep loss on physical performance, muscle recovery and exercise-induced diseases. Solid arrows reflect definite links, dotted arrows reflect probable links, and the red arrow reflects an inhibitory link. (Reproduced from Chennaoui et al).[72]

Caffeine consumption

An estimated 85% of the US population drinks at least one caffeinated beverage a day, with coffee being the primary dietary caffeine source.[82] Coffee and other caffeine containing sources, typically used to increase alertness and decrease fatigue, have negative sleep consequences. Caffeine promotes wakefulness by blocking adenosine receptors in the brain, preventing adenosine from performing its sedative effects.[83] Caffeine intake has been associated with prolonged sleep onset latency, reduced sleep duration, decreased sleep efficiency, and worse perceived sleep quality (Table 3). EEG readings demonstrate reductions in stage 3 sleep and increased amounts of stage 1 sleep, wakefulness, and arousal.[84] Older adults may be more sensitive to caffeine, and genes related to adenosine neurotransmission can influence individual sensitivity to sleep deprivation of caffeine.[84] While there appears to be genetic variation, the half-life of caffeine is 6–7 h. As a result, avoiding caffeine beyond mid-day can help increase the likelihood of achieving sleep when desired.

Limiting alcohol consumption

Alcohol is a sedative, which is associated with decreased sleep latency. However, it can disrupt sleep architecture, often resulting in awakening during the second half of the night. Alcohol increases stage 3 sleep and delays and decreases REM sleep, decreasing overall sleep quality and resulting in shorter sleep duration.[85] Furthermore, individuals who self-medicate with alcohol to help fall asleep are at risk for substance abuse problems and liver damage. There can be a fine line between passing out and falling asleep. Alcoholics often suffer from profound insomnia, daytime sleepiness, and altered sleep architecture.[85]

Table 3
Caffeine and sleep.

Effects of caffeine on sleep
• Temporary alertness and decreased fatigue • Prolonged sleep latency • Reduced sleep duration • Decreased sleep efficiency • Worse perceived sleep quality

Eating before sleeping

It is generally advisable to avoid eating within 2 h of one's desired bedtime if possible. Studies have shown that late time eating is associated with later bedtime, shorter sleep duration, and weight gain.[86] However, this may be because late time eating often involves less healthy foods. Negative outcomes of late time eating have not been consistently shown when the food choice is nutrient-dense, low energy, and/or composed of single macronutrients.[87] Avoiding large mixed meals and unhealthy foods before sleeping can help improve sleep quality and prevent weight gain. In addition, eating shortly before sleep initiation promotes GERD since the sleeping individual typically assumes a horizontal position. As mentioned, GERD has the propensity to further disrupt sleep.

Practice mindfulness

Insomnia is very often characterized by rumination with substantial and unwanted activation of the autonomic nervous system. Essentially, insomniacs very often have difficulty quieting the mind. By focusing on the breath, a mantra or a part of the body, mindfulness techniques promote a shift from sympathetic activity to parasympathetic activity which helps with sleep initiation. Mindfulness techniques can help decrease sleep-interfering cognitive processes, such as worry, anxiety, and stress.[88] Mindfulness-based interventions have been proven effective in the treatment of insomnia.[89]

Bedtime environment

Optimizing the bedroom environment also can improve sleep quality. Creating a dark, cool, and quiet sleep environment is advised. There is some data to suggest that a cooler sleep environment is associated with more deep sleep.[90] White noise machines or ear plugs can be used to drown out noise. Furthermore, refraining from using the bed for working, studying, watching television, and other non-sleep activities can be beneficial. There is no recommended sleep surface, sleep

position or pillow. An individual is advised to utilize a mattress, pillows, and bedding and to assume a sleep position which is most comfortable. However, people with untreated OSA are advised to avoid sleeping in a supine position. Furthermore, people with musculoskeletal problems often find that sleeping in certain positions results in pain and consequent sleep disruption.

Conclusions

Sleep plays a fundamental role in promoting physical and mental health by allowing the body to recover, repair, and grow. Quality sleep optimizes essentially every bodily system with extremely important benefits to the neurologic system, cardiovascular system, immune system, and endocrine system. By addressing potential underlying sleep disorders such as insomnia and sleep apnea as well as constant attention to sleep hygiene and lifestyle modification, one can substantially improve health.

Declaration of Competing Interest

None.

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