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A narrative review of the pathophysiology and impacts of insufficient and disrupted sleep

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Abstract

Background

Despite substantial ramifications of insufficient sleep on mental and physical health and general well-being, many individuals are unaware of what constitutes sufficient sleep, or of the short- and long-term extent of sleep deficiency effects, including those that may not be perceived as fatigue.

Objectives and procedures

This review describes the physiology of sleep, defines healthy standards, reviews the pathophysiology and health hazards of acute and chronic sleep insufficiency, and offers concepts for improving individual sleep hygiene. Online databases were searched to extract literature pertaining to sleep, sleep insufficiency, fatigue, and health, with emphasis on literature published in the preceding 5 years.

Results

The detrimental effects of acute and chronic sleep loss vary in their range and impact. Individuals often obtain a substandard quantity of sleep, a problem that is poorly recognized by individuals and society. This lack of recognition perpetuates a culture in which sleep insufficiency is accepted, resulting in serious and substantial negative impacts on mental and physical health.

Conclusion and clinical relevance

Sleep management is one of the most fundamental and changeable aspects of personal health. Improving awareness of the important physiological roles of sleep, healthy sleep habits, and the consequence of insufficient sleep is essential in promoting general well-being and mental and physical health.

Introduction

Sleep is a universal need experienced by all humans. While individual needs vary, normal sleep, characterized by sufficient duration and quality and appropriate timing and regularity, is essential (1,2). Lack of appropriate rest can contribute to development of chronic mental and physical health conditions (1,2). Outdated management practices and poorly designed schedules that do not incorporate time for adequate rest, societal expectations of constant practitioner availability, and historical but persistent aspects of veterinary professional culture that inappropriately emphasize sleep deprivation as evidence of motivation and dedication can all lead to prioritization of client convenience and satisfaction over veterinarian needs, making it increasingly difficult for veterinary professionals to obtain adequate rest (3,4). This can affect mental and physical health profoundly (2).

The 'fatigue paradox' describes the phenomenon whereby healthcare professionals are aware of the negative cognitive impacts of fatigue and sleep loss but fail to recognize how these affect their own cognitive abilities, professional performance, and associated risks for patients (5). The fatigue paradox also affects the clinician's ability to discern negative effects on personal mental and physical health. For veterinarians, such shortcomings blind our profession to structural problems and prevent the development of rational solutions. Sleep management is one of the most fundamental aspects of personal wellness; professional well-being cannot be achieved while we continue to require fundamentally unhealthy professional lifestyles that prevent adequate rest.

The objective of this review is to summarize the pathophysiology and mental and physical health impacts of sleep insufficiency. While most individuals intrinsically understand that regular and appropriate duration and quality of sleep are beneficial to health, it is likely that very few are fully aware of what constitutes adequate sleep and the wide range of detrimental consequences of sleep loss and fatigue.

Methods: Search strategy

A narrative review was conducted to synthesize recent literature in accordance with study objectives. One author (MS) searched the online databases Medline and Google Scholar to identify articles in several key areas on the relationship of sleep to physical and mental health that informed our review's goals. Eligible reports were those published in English-language scientific journals for the years 2017 to 2022. We restricted the initial search to the past 5 y to identify contemporary evidence. Manual scoping focused on original research manuscripts, meta-analyses, systematic reviews, and recent physician sleep society consensus statements. Selection incorporated publications obtained by identifying cited studies from articles identified in the initial search and subsequent date-unconstrained focused topic searches where additional information was needed to clarify understanding. Eligible reports consisted of those examining mental and physical health outcomes associated with sleep insufficiency, peer-reviewed articles written in the English language, and full-text articles. Animal studies and reports that focused on topics of general insomnia, non-occupational circadian rhythm disorders, parasomnias, hypersomnias, sleep-related breathing disorders, and sleep-related movement disorders were excluded.

Sleep physiology

A typical night's sleep consists of 4 to 6 sleep cycles of 90 to 120 min, each of which involves periods of non-rapid eye movement (NREM (80% total sleep time) followed by rapid eye movement (REM) sleep (20% total sleep time) (6-9). Completion of sufficient full and undisturbed sleep cycles of NREM followed by REM is important to the maintenance of circadian rhythms (9). With each new sleep cycle, increasing amounts of time are spent in REM sleep (9). Most of the total amount of REM sleep occurs in the 2nd half of the night, so short sleepers spend proportionally less time in REM (10). Rapid eye movement sleep is associated with dreaming and increased brain metabolic activity and is considered an active sleep stage. However, it is very important in processing new learning and motor skills, allocating information to memory, and processing data for critical thinking, and is essential to avoid daytime sleepiness and fatigue (11). Disruption of REM sleep on 1 night can result in further disruption of sleep cycles on the subsequent night. Insufficient REM sleep is associated with anxiety, emotional dysregulation, and concentration deficits (11). Together, NREM sleep stages 3 and 4 are known as deep or slow wave sleep, which plays an important role in cerebral restoration and recovery, including clearing of neurotoxic waste products and memory consolidation (6). Deep NREM sleep also plays a crucial role in hormone level modulation and is thought to affect individual immunity *via* induction of an endocrine milieu that supports initiation of adaptive immune responses (6). Chronotype is a behavioral trait that describes an individual’s habitual sleep-timing preferences in relation to the 24-hour light-dark cycle (12). There are large and highly replicable individual differences in chronotype, “adequate” sleep duration requirements, magnitude of fatigue experienced with sleep loss, and vulnerability of cognitive performance to acute and chronic sleep restriction (13).

Sleep insufficiency

Sleep insufficiency (*i.e.*, sleep deprivation, sleep loss, sleep deficiency) refers to a state caused by inadequate quantity or quality of sleep (1). Impactful sleep insufficiency can be caused by an acute total lack of sleep, extended wakefulness, poor-quality sleep, shortened duration of sleep, fragmented or interrupted sleep, irregular or inconsistent sleeping pattern, or circadian misalignment (1). Sleep insufficiency is particularly prevalent among healthcare workers, and inadequate sleep is often a cause or exacerbating factor for physical and mental health conditions (12,14).

The extent to which a person can attend to or engage in activity is limited by a physiological maximal processing capacity (15). Different types of information processing require different levels of attention and engagement (15). It is hypothesized that that energy resources and capacity are lost during sleep deprivation, and these losses affect the ability to expend effort and are responsible for the mental and physical performance deficits that are observed with sleep deprivation (15).

Acute sleep insufficiency describes an absence of sleep or a reduction in the usual total sleep time over a defined short-term period (usually a few days), whereas chronic insufficiency is recognized as a reduction in total sleep time (encompassing both reduced sleep and fragmented or disrupted sleep) over weeks to months. Chronic sleep losses are commonly not as well recognized by affected individuals, but additive effects over time lead to dose-dependent impacts comparable to those seen with acute sleep insufficiency (16-18).

Sleep insufficiency is associated with increased activity of the sympathetic nervous system and hypothalamic–pituitary–adrenal axis, changes in circadian rhythms, and proinflammatory responses (2). In otherwise healthy adults, consequences of sleep insufficiency on these physiologic pathways include increased stress responsivity; somatic pain; a wide array of serious metabolic alterations of the cardiovascular, gastrointestinal, endocrine, and reproductive systems; emotional distress and mood disorders; cognitive, memory, and performance deficits; and reduced quality of life (2). The greater the sleep loss or extended wakefulness, the worse the measurable performance impairments. These objective impairments are distinct from subjective ratings of sleepiness; as a result, impairment is often not clearly perceived by affected individuals (17). Similar mechanisms account for short- and long-term health consequences of sleep deficiency, although these vary with the duration of exposure to sleep loss and the degree of fragmentation (12). Separate from the magnitude of sleep duration (*e.g.*, how many hours per night one sleeps), sleep inconsistency (*e.g.*, the night-to-night variability in sleep patterns intrinsic to after-hours on-call scheduling) is implicated in physiologic dysfunction (12). Chronically disrupted or fragmented sleep (*e.g.*, repeated waking during the night for inpatient updates) also leads to sleep insufficiency that may be just as damaging to health as short-term sleep duration (12,18). Chronic sleep insufficiency reduces the body's ability to compensate for stressors, leading to cumulative effects that alter physiologic baselines, with effects on inflammation and health that are equivalent to those of multiple other demographic factors (such as age and race), and biobehavioral factors (such as body mass index and physical activity) (19). Effects of sleep loss extend beyond the central nervous system, explaining the potential for organ dysfunction across numerous biological systems (20). Reciprocally, these derangements can contribute to further sleep disruption (2,21-23).

Phenotypic responses (the manner in which an individual manifests symptoms or behaviors) to insufficient sleep quantity, quality, or consistency vary widely (13,24) and follow a normal distribution (13). Approximately 1/3 of healthy adults show profound cognitive performance deficits with even moderate sleep loss; 1/3 show moderate deficits, and 1/3 show few or no obvious performance deficits, even when sleep loss is severe (25). An average human needs ~8.16 h of sleep per 24-hour day to prevent cumulative neurobehavioral deficits, although important interindividual differences exist (26,27). It should also be noted that most humans do not fall asleep immediately but need personal wind-down time before falling asleep (28).

Regardless of individual levels of susceptibility to neurobehavioral performance deficits, all individuals are subject to other impacts (*e.g.*, mental health and metabolic derangements) of sleep deprivation. The wide-ranging effects of sleep insufficiency are often interrelated and bidirectional in their impacts on physiologic and mental health. For example, the distress associated with sleep loss can create additional stressors for an individual who feels pressured to maximize sleep, which, in turn, contributes to worsening sleep disruption (2).

Consequences of sleep insufficiency

Impact on cognitive functions

Alertness and performance decline rapidly after being awake for ~16 to 18 h (29). Alertness, reaction time, selective and sustained attention, arithmetic ability, episodic memory, working memory, and executive functions are significantly impaired after 24 consecutive h without sleep (30,31). Individuals subsequently overestimate their own vigilance performance across 3 d of recovery after sleep deprivation; this aspect that has important safety implications in professions such as healthcare (32). Disruption of deep NREM slow-wave sleep results in slower or diminished information processing, impaired sustained attention, less precise motor control, and erroneous implementation of well-practiced actions (33). Acute sleep insufficiency also results in reduced capacity to maintain attention proportional to the increasing hours awake (34). A meta-analysis of 60 studies (35) concluded that, with 24 to 30 h of sleep deprivation, the cognitive performance of an average person (mid-cohort) dropped to a level comparable to that of individuals in the 15th percentile of the rested group. Strikingly, when sleep-deprived, the clinical performance of the typical physician decreased to a level comparable with that of individuals in the 7th percentile of a comparison rested group (35).

Cognitive impairment can be experienced following chronic sleep restriction (< 7 h of sleep per night) to levels that are comparable with those observed with acute total sleep loss (24). Compelling evidence of residual and differential (the magnitude of deficit is not equivalent across symptoms) neurobehavioral deficits exists following both chronic partial sleep restriction and acute total sleep deprivation; and very importantly, even 4 consecutive nights of 12-hour time-in-bed recovery is not enough to reverse these deficits (36). "Catching up on sleep" on the weekends (a popular remedy for sleep loss) is often insufficient to return individuals to baseline cognitive function (37,38). While chronic sleep insufficiency results in cumulative cognitive performance deficits in most healthy adults, not all individuals are affected to the same degree (24). Neurobehavioral responses to sleep loss are stable and reliable within individuals, suggesting a genetic component to this expression, although individual vulnerability may evolve and vary with age and life stage (24,25,39,40).

While observed sleep-related cognitive impairments are reliable and repeatable within an individual, the degree of impairment may be different within different types of cognitive expression (17). For example, a person may exhibit greater deficits in executive function *versus* arithmetic ability. Additionally, even after 8 to 12 h of recovery sleep, individuals with recent chronic sleep loss may be more vulnerable to additional sleep restriction. Compared with performance when recovery sleep is not preceded by chronic sleep debt, acute sleep restriction in addition to chronic reductions can result in a 2- to 10-fold deterioration of task performance.

(24,41). Work schedules that cause chronic sleep restriction and limit consistent recovery sleep may cause progressive deterioration in performance despite intermittent opportunities for recovery sleep (41). Individuals exposed to such schedules can become increasingly vulnerable to the adverse performance effects of acute sleep loss with subsequent exposure (41).

Even when cognitive effects are not immediately observed, chronic sleep patterns demonstrably impact learning and performance. In college students, sleep of longer duration, better quality, and greater consistency for the month and week before a test correlated with better grades than for those recording poorer sleep parameters (42). This finding highlights the importance of adequate rest during periods of learning for optimal memory consolidation. In another study, students who averaged ≥ 8 h of sleep during the week of final exams performed significantly better than students who chose not to participate or who slept less than 8 h (43). Negative effects on learning, memory, and performance are also seen with sleep inconsistency (day-to-day variation in sleep schedule, duration, or both), often manifesting in sleep debt during weekdays followed by oversleeping on weekends (42). Sleep is thought to play a crucial function in memory consolidation, retention, and recall – all of which are essential for learning and performance. This effect appears modulated primarily during NREM sleep (44), although REM sleep plays a major role in critical thinking and complex problem solving (45). The impacts of insufficient sleep on learning, memory, and analytical skills have important ramifications not only in veterinary education, but for all veterinary professionals for whom complex problem-solving is regularly required and ongoing learning is imperative.

An enormously important role of sleep is the opportunity it provides to clear undesirable metabolic byproducts in the brain, including amyloid-β, which is associated with impairment of brain function and is a risk factor and hallmark for Alzheimer's disease. A significant increase in amyloid accumulation in the brain relative to baseline can result from just 1 night of sleep loss, regardless of any genetic risk for Alzheimer's disease (46,47). Rising risks of dementia in old age are increasingly shown to be associated with chronic sleep insufficiency and disruption, especially when this poor sleep occurs in middle age (48,49). Six hours or less of daily sleep on a regular basis at the ages of 50 y (OR: 1.28, 95% CI: 1.06 to 1.55) to 60 y (OR: 1.48, 95% CI: 1.19 to 1.84) increased the risk of developing dementia by 30 to 40% (48). Sleep disturbances may also increase the risk of developing Parkinson's disease *via* effects on dopaminergic neurons (50,51).

Impact on mental health

Adults with chronic sleep insufficiency increasingly report depressive symptoms and anxiety (50), as well as excessive mental distress and alcohol consumption (52,53). Chronic sleep insufficiency from long-term partial sleep losses can have profound effects that are frequently underestimated, altering mood to an even greater extent than immediately appreciable cognitive or motor functions (54). Chronic sleep restriction may gradually alter not only the neuroendocrine stress response system, but also the central mechanisms involved in the regulation of these responses (12,19). Prefrontal cortical networks, which are integral to decision-making and emotion regulation, are some of the most susceptible to sleep loss (55). Sleep deprivation may confer vulnerability to more emotionally driven behavior through a combination of reduced prefrontal cortex and increased amygdala activation (55).

Importantly, sleep insufficiency may gradually change certain brain and neuroendocrine systems in a manner similar to what occurs in stress-related disorders such as depression (12). Connectivity and processing within and between the amygdala, anterior cingulate, and medial prefrontal cortex is disrupted, resulting in emotional dysregulation (34). Sleep-deprived individuals express a generalized excess of emotional sensitivity, but the specificity with which they interpret the emotional aspects of facial expressions and other interpersonal communications is impaired (56). With insufficient sleep, individuals tend to rate neutral images as more emotionally negative (17). In response to frustrating or negative events, sleep-deprived physicians exhibit intensified negative emotional responses (57). They also demonstrate an elevated baseline for positive emotional affect and exhibit reduced positive emotion in response to goal-enhancing or positive events (57). Sleep deprivation impairs the accurate discrimination of facial signals, promoting an overall bias towards increased (but inaccurate) perception of negative affect or threat, which can cause communication challenges (17). The end result is that sleep insufficiency decreases one's ability to discern and mirror emotions, which may diminish the affected individual's capacity for empathy and interpersonal engagement (17,56,58,59).

Disrupted sleep has been established as a major contributor to the development of depression and anxiety (60), and sleep deficiency is associated with suicidal thoughts and behaviors (19,61,62). Deficiencies in NREM sleep in particular are harmful to the consolidation of positive emotional content, impacting mood and reactivity; and are also tied to the severity of mental health disorders, including suicidal ideation or behaviors (63). It is increasingly clear that there is a bidirectional relationship between sleep and mental health, and that ensuring adequate sleep has both preventive and therapeutic roles in mental health (64). The combination of increased activity in the impulsivity and reward centers of the striatum and decreasing activity in the prefrontal cortex suggests that sleep loss can lead to more polarized swings in mood, not just depression. In addition to its impacts on mood disorders, insufficient sleep may contribute to the development and maintenance of other reward dysfunction-related disorders, such as compulsive gambling, eating, and substance abuse (55).

Impact on other body systems

Circadian misalignment and sleep insufficiency are associated with increased risks of serious and diverse health disorders including cardiovascular disease, hypertension, stroke, obesity, metabolic syndrome, type 2 diabetes mellitus, Alzheimer's disease, and overall non-specific increased mortality (2,12,13,24,65). Sleep deficits may worsen the symptoms of inflammatory bowel disease, irritable bowel syndrome, and gastroesophageal reflux disease (2,66). Endocrine impacts of sleep fragmentation and restriction result in elevated cortisol levels, increased sympathetic activation, decreased thyrotropin activity, reduced insulin sensitivity, and reduced glucose effectiveness (defined as the ability of glucose to mobilize independent of an insulin response) (24). Experiments in selective slow-wave sleep deprivation without any change in total sleep time resulted in a marked decrease in insulin sensitivity by ~25% (reaching the level reported for populations at high risk for diabetes) without an adequate compensatory increase in insulin release (67). Chronic sleep insufficiency is associated with reduced leptin, elevated ghrelin, and increased body mass index (68,69). A hormonally mediated increase in appetite may help to explain why short sleep is related to obesity. Evening or early morning shift work is strongly associated with metabolic syndrome (OR_{Total}: 2.72, 95% CI: 1.38 to 5.36) compared to working standard day shifts (70). Night shifts are commonly associated with shorter sleep times than day shifts, and among this cohort, each additional hour of sleep decreases the odds of metabolic syndrome (OR: 0.52, 95% CI: 0.33 to 0.82) (70).

Meta-analysis of 11 studies demonstrated that short sleep duration (RR: 1.21, 95% CI: 1.05 to 1.40) and sleep continuity disturbance (RR: 1.20, 95% CI: 1.06 to 1.36) increase the relative risk of hypertension, which is a major source of morbidity and mortality affecting 47% (116 million) of adults in the United States (71-74). Compared to sleeping 6 to 9 h per night, those sleeping < 6 h per night have a 20% higher risk of myocardial infarction; and importantly, healthy sleep duration mitigated myocardial infarction risk even among individuals with high genetic risk (75). While blood pressure normally decreases during the night to provide important rest to the cardiovascular system, sleep deprivation has been associated with a non-dipping pattern of hypertension, and patients who do not experience normal blood pressure decreases are suggested to have a higher risk of stroke (76,77). Just 1 night of acute sleep deprivation in on-call physicians has been shown to affect factors important in the pathophysiology of hypertension, increasing cardiac sympathetic modulation, affecting the capability of autonomic neural control to correctly respond to a stressor stimulus, and modifying an immune pro-inflammatory profile, increasing plasma levels of IFN-γ (729.8 *versus* 455 pg/mL; $P < 0.05$) (78).

Other studies report an association between chronic sleep disruptions and increased risks for development of different forms of cancer, including those of the breast, prostate, colon, and rectum. The International Agency for Research on Cancer concluded in 2007 that employment involving circadian disruption is probably carcinogenic to humans (79,80). Disruption of the circadian rhythm and sleep deprivation have been shown to accelerate tumor formation, and epidemiologic studies have demonstrated positive associations between rates of a number of different cancers and overnight work (2). Exposure to light at night decreases production of melatonin, which, in addition to its role in the circadian rhythm, also acts as a potential free radical scavenger. Chronic reductions in melatonin may lead to reductions in DNA repair, inhibition of tumor growth, and production of reproductive hormones (2). Insufficient sleep is associated with reproductive issues in women, including menstrual irregularities and difficulties in conception or maintaining pregnancy (12).

Sleep losses affect immune function in a reciprocal manner, leading to changes in proinflammatory cytokines such as tumor necrosis factor, interleukins 1 and 6, and C-reactive protein (66,81,82). Sleep insufficiency has been associated with altered innate and adaptive immune responses: Very recently, it was demonstrated that pre-existing reduced sleep duration at night, sleep problems, and night shifts were robustly associated with increased risks of contracting infectious diseases, including COVID-19 (21,22,83-85). In a cohort of healthcare workers, every 1-hour increase in sleep duration at night was associated with 12% lower odds of contracting COVID-19, whereas having severe sleep problems was associated with 88% higher odds of contracting COVID-19 (85).

Individual actions to improve sleep

Causes of sleep loss are multifactorial and fall into 2 major and somewhat overlapping categories: lifestyle/occupational causes (*e.g.*, work factors, irregular sleep schedules, jet lag, environmental disruptions) and sleep disorders. Education on sleep requirements and the health impacts of sleep insufficiency is essential to developing healthy sleep practices (86). This may be especially useful to those in occupations with high rates of insufficient sleep, such as those working in healthcare. Unfortunately for many, habits developed early in one's life and career may impair sleep quality or quantity for years if not corrected. Those who experience frequently inadequate sleep duration or repeated sleep disruptions are often not consciously aware of their accumulating sleep deficits or the effects on their cognitive functions, psychological well-being, or physical health (51). People struggling with achieving sufficient quantity or quality of sleep despite allowing adequate time for sleep should avoid labeling this problem as "genetic" or "unfixable". Insomnia as a secondary effect of a wide variety of other medical conditions is common, and consultation with a general practice physician is an important 1st step if one is experiencing insomnia (86). However, many others unwittingly self-impose sleep insufficiency *via* personal habits and environmental factors, and those who identify poor sleep quality or quantity despite allocating adequate time for sleep time may be able to improve their sleep through behavioral modification and attention to sleep hygiene. However, occupational factors also play a large role in shaping sleep opportunity and quality; these are discussed in a companion manuscript (87). More detailed sleep hygiene tips are outlined in Table 1.

Although prescription and over-the-counter sleep aids are frequently marketed to improve sleep, many sleep experts consider chronic use of sleep medications and other aids, such as melatonin, to be minimally effective at best and harmful at worst (88,89). Recognizing the complex science behind sleep and the critical role of sufficient sleep in maintaining mental and physical health, individuals suffering from chronic sleep insufficiency that has not been adequately improved by environmental and behavioral modifications or treatment of underlying medical conditions should consider consultation with a physician specializing in sleep medicine.

Conclusions

Among the known risk factors for reduced health, sleep deficiency has some of the greatest negative impacts, yet it is one of the most manageable aspects of personal health that an individual can address. Given the preponderance of detrimental effects of sleep insufficiency on cognitive function, memory, knowledge assimilation, and personal mental and physical health, prioritization of sleep hygiene is imperative. This is particularly relevant to members of the veterinary profession, which is suffering from high rates of poor mental health and burnout. Factors negatively affecting personal sleep quantity and quality should be carefully evaluated by veterinary professionals. Individuals experiencing chronic sleep loss should actively revise work and personal practices to improve sleep hygiene, including consulting with physician sleep specialists as needed.

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Table 1. Sleep hygiene for individuals demonstrated to aid/improve sleep (88, 90-100).

Sleep hygiene factor	Implementation advice	Impact on sleep
Sleep duration	Aim for 7 to 9 h of sleep/night.	Prevents accumulation of sleep deficits
Sleep schedule	Go to bed when sleepy, preferably at a similar time each night; maintain regular wake time. Maintain a regular sleep schedule even on weekends and vacations.	Circadian rhythm regulation
Daytime naps	Many suggest avoiding daytime naps if on standard daytime schedules, but research is unclear. If needed, limit nap duration to 20 to 30 min. Appropriately planned naps have proven benefit for night shift workers.	Circadian rhythm regulation; avoids reduced sleep pressure at night
Exercise	Exercise regularly, but limit activity immediately prior to bed.	Circadian rhythm regulation; at least 60 min of exercise 4 to 8 h prior to bedtime creates greatest increase in total sleep time
Diet	Consume a balanced diet.	Diets high in carbohydrates may increase risks of insomnia. Adherence to the DASH diet may reduce odds of insomnia.
Meal timing	Reduce fluid intake before bedtime. Do not eat a large meal close to bedtime; if hungry, eat a light snack.	Eating or drinking close to sleep can cause gastrointestinal reflux or stimulate need to urinate and interrupt sleep.
Alcohol consumption	Limit alcohol consumption; avoid within 4 h prior to sleep.	Even light alcohol consumption near bedtime is associated with delayed sleep onset and next-day fatigue. Large amounts may induce near-term sleepiness; however, even limited alcohol inhibits REM sleep and memory integration.
Caffeine consumption	Limit caffeine use; cease ingestion 6 to 8 h prior to sleep.	A stimulant by competitive inhibition of adenosine; affects ability to initiate and maintain sleep; single dose half-life 3 to 7 h (effect lasts longer with age)
Light exposure	Limit evening exposure to bright light.	Circadian rhythm regulation; dimming light triggers melatonin release
Electronic devices	Turn off devices 60 min prior to bedtime to limit blue light exposure; consider setting an alarm to maintain temporal separation. Use software that reduces blue LED light emission or consider light-blocking glasses.	Circadian rhythm regulation; ocular "day" receptors are most sensitive to blue LED wavelengths common in electronics, leading to melatonin suppression
Bedroom environment	Create a quiet, relaxing space with limited light and noise. Consider earplugs, white noise, and/or eye masks.	Limits external factors that may interrupt sleep
Bedroom temperature	Reduce bedroom temperature (ideally 65°F/18°C). Alternatively, reduce core body temperature by warming hands/feet or taking a warm bath.	Cooler temperature triggers sleep induction.
Bedtime activities	Manage stress that induces cognitive arousal (worry, anxiety). Minimize stress before bedtime with mindfulness techniques. Only use the bed for sleep or intimacy and generally avoid mentally	Quieting mental activity promotes sleepiness.

	stimulating activities while in bed in favor of relaxing ones.	