### Key Points

- Disturbed sleep is associated with a wide range of chronic disorders including metabolic, cardiovascular, inflammatory, mood, and cancer diagnoses.
- Circadian biology provides a rich scientific framework for understanding connections between sleep and chronic disease, as well as numerous lifestyle interventions for alleviating sleep disturbances and enhancing the restorative and therapeutic benefits of sleep.
- The timing and intensity of light exposure has a profound effect on sleep quality, and many simple lifestyle modifications can be deployed to optimize the sleep-light relationship.
- Circadian-based diet, temperature, activity, and coping interventions provide additional lifestyle strategies for enhancing the therapeutic benefits of sleep.

### 85.1 Sleep is Fundamental to Health

Although we spend nearly one-third of our lives sleeping, there is still much to learn about why we need sleep, what causes us to sleep, and how to optimize the benefits of sleep. One attribute of sleep for which there is significant and growing evidence is the strong correlation between inadequate sleep and a broad range of chronic diseases.

In parallel with the growing incidence of chronic disease, there has been a significant decrease in the quantity of time spent sleeping, and in the past 40 years, U.S. adults’ average hours of sleep per night has declined nearly 30%. In addition to this significant reduction in average hours of sleep, nearly 50 million U.S. adults report recurrent difficulties getting restful sleep.\(^1\) While the etiology of many chronic diseases is multifactorial, there is compelling evidence that both shortened sleep and poor-quality sleep are significant contributory factors.

It is good news that Lifestyle Medicine has much to offer patients by using lifestyle interventions to enhance both the quantity and quality of sleep, and thereby realizing the therapeutic potential of sleep as medicine. In this chapter, the correlations between high prevalence chronic diseases and inadequate sleep will be described. Following this focus on disease correlates, the known circadian biology-based elements of sleep that are influenced by lifestyle will be reviewed. Based on this scientific foundation, lifestyle-based interventions to enhance sleep’s therapeutic power will be explored.

### 85.2 Sleep and Chronic Disease

#### 85.2.1 Excessive BMI and Metabolic Disorders

Ample evidence shows short sleep duration adversely affects appetite and metabolism. One predominant effect of short sleep duration is an associated increase in appetite and food seeking behavior.\(^2\) The mechanism for this effect is thought to be through increase in adipocyte release of leptin, an appetite-stimulating hormone. In one study, healthy volunteers consumed 300 to 500 additional kcals following a single night of only four hours of sleep,
particularly of carbohydrate-rich foods. In other studies, shortened sleep has been shown to increase nocturnal cortisol levels with a concomitant increase in serum glucose.3 A potential mechanism for shortened sleep may be the adverse effect of low daytime light levels’ impact on metabolism. This is based on theoretical evolutionary and circadian biology: in non-equatorial geographies an adaptation to food scarcity during winter was to increase appetite and food seeking behavior during the longer days of summer when food is most abundant, thereby building up a body weight reserve for winter. Along these same lines, lower light levels during winter appear to slow metabolism which would assist with conserving body reserves through the shorter days of winter.4 Secondary to metabolism, but still very relevant to weight control and healthful dietary intake, inadequate sleep has also been found in some studies to correlate with reduced impulse control. In turn, reduced impulse control may increase risk for overweight and metabolic disorders through increased consumption of nutritionally poor and excessive quantities of food.5

85.2.2 Cardiovascular Diseases

The relationship between cardiovascular disease and poor sleep is best understood as it relates to hypertension and coronary artery disease. The early clues to the importance of sleep for cardiovascular health came from epidemiological studies that found significantly increased incidence of both conditions among night shift workers. Short sleep has also been found to correlate with increases in sympathetic balance and vascular tone, which over time could contribute to increased CVD risk.6

Looking specifically at hypertension and sleep, one of the hallmarks of normal blood pressure regulation is the presence of a blood pressure nadir during the middle of the sleep cycle. Short sleep duration has been associated with blunting of the mid-sleep blood pressure drop, and further, the dimensioning or absence of this blood pressure nadir has been found to precede the development of clinically elevated daytime blood pressure. Additionally, the increased vascular tone and sympathetic activation seen following sleep loss may be related to decreased nocturnal endothelial nitric oxide production, which plays a critical role in nocturnal vasodilation and the restorative slow wave phase of sleep.7,8

Looking at CAD and sleep, possible mechanisms by which poor sleep could increase risk for coronary dysfunction appear to stem from endothelial inflammation. Just one night of short sleep has been shown to correlate with increased markers of endothelial inflammation and adhesion. As will be discussed below, sleep loss has also been found to correlate with increased production of Interleukin-6 (IL-6) and Tumor Necrosis Factor (TNF), which has in turn been linked with increased risk for the development of heart failure.9

85.2.3 Mood Disorders

Disturbed sleep has been found to correlate with a wide spectrum of adverse mood changes including increased negative affect, increased anxiety, greater stress reactivity, increased interpersonal conflict, and decreased positive affect. While it is difficult to discern whether sleep loss is the antecedent to or result of mood disturbance, several prospective studies have found that sleep loss increases the risk for and incidence of future development of major depression and anxiety disorders, especially among adolescents.10,11

85.2.4 Inflammatory Disorders

As mentioned above, both short- and longer-term sleep loss have been found to correlate with increased production of many proinflammatory markers, such as IL-6, C-reactive protein (CRP), and, in some circumstances, TNF, via increased transcriptional activities. In some studies, this effect has been found to be much more significant in women than men as well as in socially isolated individuals. By extension, the proinflammation effect of sleep loss may underlie the associations between disturbed sleep and numerous chronic diseases including CAD, type II diabetes, rheumatoid arthritis, multiple sclerosis, cancer, and depression.9

Based on meta-analysis, the effect size of sleep disturbance on proinflammatory markers has been found to be greater than elevated marker levels found with tobacco use, sedentary activity and low socioeconomic status. In the opposite, absolute changes in IL-6 and CRP associated with elimination of sleep disturbance have been found to be equivalent to the absolute changes associated with aerobic exercise and healthy dietary interventions.5

85.2.5 Cancer

Night shift work is associated with increased risk for several cancers including breast, prostate, and colon malignancies. Other studies have looked at correlations between greater exposure to light at night and breast cancer incidence and have found suggestive positive associations. A possible physiological mechanism starts with the association between sleep disturbance and increased activity of genes related to DNA damage response (DDR). Similarly, many methylation and de-methylation DNA repair processes occur during sleep and may be disrupted by sleep loss. Another possible contributory mechanism for the associations between sleep disturbance and cancers is the enhanced cellular arrest and cell senescence seen in individuals following sleep curtailment and/or sleep disturbance.12,13

85.3 Circadian Biology in Relation to Sleep

There are several different physiologic frameworks from which to study and understand sleep; however, the discipline of circadian biology provides an evidence base for optimizing sleep that is particularly well suited to lifestyle medicine.

While still in the early stages of translation from basic science to clinical application, the field of circadian
85.3.1 Sleep and Light
At its core, the sleep–wakefulness cycle is one of the most fundamental manifestations of the circadian system. Equally fundamental, and in keeping with the elemental nature of the sleep–wake cycle, the 24-hour alternation between daylight and darkness is the predominant regulator of the sleep–wake cycle.

As has been understood for many decades, the onset of dusk and darkness at night leads to secretion of melatonin from the pineal gland, which is strongly correlated with the onset of drowsiness and sleep. What has also been demonstrated in many studies is that even dim light, such as that from backlit screens and digital displays, causes melatonin suppression. The degree of suppression varies depending on at least several factors: the brightness of the light; the duration of exposure; the color spectrum of the light; and the amount of daytime light exposure.14

The first two factors, brightness and duration, are relatively straightforward: the longer the exposure—or the brighter the light—and the greater the duration and degree of melatonin suppression. Regarding the color spectrum of the light, what has become more apparent in the past 10 years is that the more blue wavelengths in the light (~480nm), the greater the suppressive effect on melatonin. In application, this means monochromatic blue light, such as that produced by blue appliance display lights, causes melatonin suppression. The degree of suppression varies depending on at least several factors: the brightness of the light; the duration of exposure; the color spectrum of the light; and the amount of daytime light exposure.14

85.3.2 Sleep and Thermoregulation
Another feature of the circadian system that profoundly influences sleep and its quality is the diurnal alternation in core body temperature (CBT). In healthy individuals, core body temperature fluctuates nearly two degrees Fahrenheit between its nadir during sleep and its peak in the late afternoon. The mechanism leading to core body temperature cooling during sleep is a profound increase in cutaneous vasodilatation that, in turn, results in heat being released from the surface of the skin into the air. The onset of this cutaneous vasodilatation is strongly correlated with the onset of drowsiness that leads to sleep onset. Ongoing release of heat through the skin continues until about four hours after the onset of sleep.17,18

Conditions that cause insufficient cutaneous vasodilatation have been found to suppress the onset and maintenance of sleep. For example, individuals with vasospasm almost uniformly report insomnia and difficulty initiating and maintaining sleep. Microvascular damage secondary to diabetes is also thought to contribute to sleep difficulties commonly reported by individuals with diabetes. Excessive sympathetic activation, inadequate fluid hydration, daytime sedentary activity, as well as excessive carbohydrate and sodium intake before bed can each contribute to disruption of effective CBT cooling and sleep quality.19,20

85.4 Sleep Assessment
Regardless of whether the patient presents for lifestyle interventions to address primary, secondary, or tertiary prevention needs, the assessment of sleep is a cornerstone of Lifestyle Medicine evaluation.

The number of hours of sleep per 24-hour period is the obvious initial consideration, with seven to nine hours being appropriate for most patients. Sleep durations less than six hours and more than nine hours are the sleep duration extremes most strongly correlated with adverse health effects and chronic diseases. When a patient reports sleeping less than seven hours per 24-hour period, an important distinction is whether sleep duration is curtailed voluntarily, or due to difficulty initiating or remaining asleep. Next, subjective sleep quality should be assessed specific to soundness of sleep and subjective restorative effect. With individuals reporting poor sleep quality, both the period of sleep that is disturbed (onset of sleep, maintenance of sleep, offset of sleep), and the patient’s level of distress about the sleep difficulties should be probed.

Any patient reporting interrupted sleep or sleep that is not refreshing should be asked about the degree of daytime fatigue and tiredness. Significant chronic daytime fatigue should trigger evaluation for obstructive sleep apnea (OSA), especially in the context of excessive BMI and hypertension. The STOP screening tool can assist with identification of patients at risk for OSA: S is for loud snoring; T is for tiredness; O is for observed apnea during sleep; and P is for elevated blood pressure, and the presence of two or more of these factors should trigger referral for an OSA evaluation and sleep study.

Regularity and typical time for going to bed, as well as regularity and typical time for getting up, should be documented. Distinguishing voluntary irregularity and short sleep duration from involuntary irregularity and short sleep, due to sleep disturbances, is important to the
selection of appropriate lifestyle interventions to support improved sleep health.

Following the assessment of sleep duration, quality, regularity, OSA risk, and improvement goals, key lifestyle domains that affecting the therapeutic potency of sleep should be evaluated (see Table 85.1). These domains include the lifestyle habits related to daytime and nighttime light exposure, dietary habits related to the timing and composition of meals, routine environmental conditions and activities impacting the core body temperature cycle, and regular use of relaxation techniques to reduce stress before bed.\textsuperscript{21,22}

### TABLE 85.1 Lifestyle interventions for sleep

<table>
<thead>
<tr>
<th>Lifestyle Behavior</th>
<th>Falling asleep</th>
<th>Staying asleep</th>
<th>Sleeping 'til morning</th>
<th>Waking up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low light before bedtime\textsuperscript{1}</td>
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<td>More morning light\textsuperscript{2}</td>
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<td>More afternoon light\textsuperscript{3}</td>
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<td>Earlier breakfast\textsuperscript{4}</td>
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<td>Later breakfast\textsuperscript{5}</td>
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<td>More breakfast\textsuperscript{6}</td>
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<tr>
<td>Earlier dinner\textsuperscript{7}</td>
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<tr>
<td>Later dinner\textsuperscript{8}</td>
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<tr>
<td>Bigger dinner\textsuperscript{9}</td>
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<td>Smaller dinner\textsuperscript{10}</td>
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<tr>
<td>Less salty/spicy dinner</td>
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<tr>
<td>More daytime water</td>
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<tr>
<td>Less nighttime water\textsuperscript{11}</td>
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<tr>
<td>No evening caffeine</td>
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<td>No afternoon caffeine</td>
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<tr>
<td>Min/no evening alcohol</td>
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<tr>
<td>Morning exercise</td>
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<td>Mid-afternoon exercise</td>
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<td>Before dinner exercise</td>
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<tr>
<td>More physical activity</td>
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<tr>
<td>Bedtime calming habit</td>
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<td>Mid-night calming habit</td>
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<td>Wakeup calming habit</td>
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<td>Cooler bedroom</td>
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<tr>
<td>Warmer bedding\textsuperscript{12}</td>
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</tr>
<tr>
<td>Cooler bedding</td>
<td>**</td>
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</tbody>
</table>

\textsuperscript{1} 60–90 min before bedtime, no screens, amber glasses alternative
\textsuperscript{2} 10–20 min, within 2 hrs after wakeup time, not too much earlier than ideal wakeup time esp. summer
\textsuperscript{3} 15–20 min, after 3 pm
\textsuperscript{4} Within 45 min of ideal wakeup time
\textsuperscript{5} No food or caffeine until 45 min after ideal wake up time
\textsuperscript{6} At least 30% of daily calories, no skipping breakfast
\textsuperscript{7} Finish eating at least 3 hours before ideal bedtime
\textsuperscript{8} No closer than 2 hours before ideal bedtime, only if eating very small, low-carb dinner
\textsuperscript{9} Not to exceed 30% of daily calories
\textsuperscript{10} Max 30% of daily calories, low carbs-esp. not simple carbs
\textsuperscript{11} If waking up because need to go to bathroom
\textsuperscript{12} Usually only helpful if having cold hands and/or feet
85.5 LIFESTYLE PRESCRIPTIONS FOR OPTIMAL SLEEP

Although translation of circadian biology to therapeutic and lifestyle applications is still in its infancy, the current science provides ample opportunities to apply simple lifestyle modifications that can significantly improve the therapeutic and performance benefits of high-quality sleep. In this section, the indications and relative efficacy of each sleep enhancing lifestyle modification will be discussed.

85.5.1 Light Exposure Interventions for Sleep

As has been described above, light exposure is one of the most potent regulators of sleep duration and quality. The two most general lifestyle behaviors consistent with optimizing sleep are to (1) minimize exposure to light at night and (2) assure at least 30 to 60 minutes of daytime exposure to natural light, ideally in the early morning and late afternoon.

Minimizing exposure to light at night, and resultant greater melatonin secretion, can be achieved in a wide variety of ways:

- Turn off all unnecessary lights at least 60–90 minutes before bedtime;
- Avoid using backlit screens (phone, e-reader, monitor, TV) during the 60 to 90 minutes before bed;
- If use of backlit devices before bed is not acceptable, amber lens colored glasses will filter out much of the blue wavelength light and reduce the amount of melatonin suppression cause by the screen light;
- Remove or cover all digital display devices such as alarm clocks and TV control panels;
- Use window coverings to block light intrusion into the bedroom from streetlights, headlights, and nearby buildings;
- When lights must be left on at night for safety, the lowest possible wattage bulb should be used, and, ideally, the bulb or cover is yellow or amber (e.g. bug light bulb);
- If getting up at night to use the bathroom or tend to a family member is necessary, avoid turning on lights, if possible, and if lights are necessary, use amber light-emitting bulbs, or wear amber lens colored glasses to minimize blue wavelength exposure.

These nighttime light exposure modifications are especially effective for individuals that are prone to staying up too late; that have difficulty falling asleep within 20 minutes of going to bed; and/or that have difficulty staying asleep until morning. The above strategies can also benefit individuals that do not have any of the sleep onset or maintenance complaints listed above, but do not wake up feeling refreshed, by enhancing slow wave sleep during the early stages of sleep.

We turn next to sleep-enhancing lifestyle modifications related to daytime light exposure. The benefits of this sleep-enhancing lifestyle strategy can best be achieved by the following daily routines:

- Spending at least five to ten minutes outside under the open sky as early in the morning as is practical each day (10–20 minutes is even better);
- Spending as much time as practical near windows with bright natural light;
- Using bright indoor lighting (minimum 150 watt equivalent or more) when away from bright natural lighting; this is especially important for individuals that spend the majority of their daytime hours indoors with typical lighting levels (e.g. office building lights); and
- Sleeping in a bedroom that has eastward facing windows, or using a dawn simulation alarm clock that gradually brightens the bedroom.

This last intervention has been shown to be effective for improving the transition from sleep to wakefulness—both subjectively, in terms of post-awakening alertness, and objectively, through enhancement of the cortisol awakening rise. It can be particularly effective for individuals that report sleeping sufficient hours each night but nonetheless have difficulty getting out of bed, or remain sleepy after awakening, in the morning.

The other daytime light exposure strategies can be especially beneficial for individuals that have difficulty initiating and maintaining sleep, especially if avoidance of bright light at night is not practical.

85.5.2 Dietary Habits for Sleep Enhancement

Another set of sleep-enhancing lifestyle modifications arise from the impacts on sleep of meal timing and the distribution of total daily carbohydrates.

Starting first with breakfast, the old adage to eat breakfast like a king or queen seems to hold true in relation to the cortisol awakening rise (CAR), which is enhanced by routinely consuming a significant proportion of the total daily carbohydrate intake at breakfast. This CAR-enhancing effect is further strengthened by breakfast being consumed within the first hour after awakening. The theory explaining the relationship between breakfast and enhanced CAR is that after the fasting state that occurs during sleep, it is the metabolic anticipation of a carbohydrate-rich meal that controls the strength of the CAR signal.

As discussed earlier in this chapter, CAR has a significant positive effect on the transition from sleep to wakefulness, with stronger CAR signaling correlating with greater subjective alertness upon morning time awakening. For individuals that have difficulty waking up and/or delayed morning alertness, routinely timing breakfast to within the first hour after waking up can be therapeutic. Additionally, consuming the largest proportion of total daily carbohydrates at breakfast can further remedy slow and delayed transitioning from sleep. For individuals that awaken an hour or two earlier than seven to eight hours after bedtime, delaying breakfast until an hour after awakening can be helpful.
At the other end of the meal timing and total daily carbohydrate spectrum, these aspects in relation to dinner can also significantly impact sleep quality. Both dinner and night time snacks, when consumed within two hours of bedtime, have been shown in some studies to delay the onset of sleep. This delaying effect is significantly stronger when carbohydrate-rich foods are consumed close to bedtime. The theoretical explanation for the sleep-delaying effect of high carbohydrate foods is that the heat of digestion raises core body temperature (CBT). As was discussed earlier in this chapter, CBT cooling is a critical feature of sleep onset, and the heat of digestion close to bedtime raises CBT during the part of the CBT cycle when it should be dropping.

Based on these night time meal and sleep onset relationships, avoidance of night time snacks, eating dinner earlier, and reducing night time consumption of carbohydrate-rich foods can benefit sleep in individuals that tend to stay awake too late, and/or that have difficulty falling asleep within 20 minutes after going to bed.

Another opportunity for dietary lifestyle modifications to enhance sleep is related to the consumption of carbohydrate-free, non-caffeinated, non-alcoholic fluids. The profound increase in cutaneous blood flow, in the hour before sleep onset and during the first half of the sleep cycle, is the mechanism resulting in CBT cooling. The functioning of this cooling mechanism depends on a reduction in peripheral vascular tone and an increase in cardiac output, of up to 60%, in order to occur. When hydration is poor and vascular tone is subsequently higher, CBT cooling can be blunted or inhibited completely.24–26

85.5.3 Thermal Regulation Interventions for Sleep

The application of this hydration-CBT cooling relationship lies with individuals that have difficulty getting to sleep and/or maintaining sleep through the first four to six hours of the sleep cycle, especially in the presence of poor water consumption habits. Individuals that report cold or cool extremities at bedtime are particularly likely to experience enhanced sleep quality by increasing water intake throughout the day.

Other lifestyle-based means for enhancing the CBT cooling process during sleep is through modification of the ambient temperature in the bedroom. Comparisons of CBT cooling during sleep between a stable ambient temperature vs. a gradually decreasing ambient temperature have shown that a gradual decrease in ambient temperature is associated with enhanced CBT reduction and improved subjective sleep quality. In application, sleep quality can be improved by setting the thermostat low enough to allow gradual cool of the bedroom temperature, using lighter bedding, or opening a window so that the bedroom cools as outside night time temperatures drop. This sleep enhancement strategy can be particularly effective for individuals that report difficulty in maintaining sleep throughout the night.27

85.5.4 Mindfulness and Cognitive Behavioral Therapy Interventions for Sleep

Numerous studies of cognitive behavioral therapy for insomnia (CBTI) and mindfulness meditation (MM) interventions have demonstrated beneficial effects on sleep quality, especially those elements of these interventions that replace rumination, problem-solving, and planning thought patterns during night time wakefulness with sensory-focused attention and mental relaxation. Online and group delivery of CBTI and MM have also been found to be effective. Integration of a nightly relaxation routine, such as sensory-focusing attention techniques (e.g. observing the breath), provides therapeutic enhancement of all stages of sleep, especially for individuals that experience long periods of wakefulness and inability to return to sleep. Although a predominant mechanism of action for the effect of mind calming and relaxation techniques on sleep quality has not been clearly identified, reduced sympathetic tone with resultant improved cutaneous vasodilatation and core body cooling appears to be a contributing factor.28,30

85.6 CONCLUSIONS

Therapeutic sleep consists of both sufficient duration and restorative quality. Lifestyle Medicine provides an ideal context for prescribing lifestyle modifications that greatly enhance the therapeutic benefits of sleep. Whether prescribing sleep enhancement interventions for primary prevention and optimal performance, for secondary and tertiary prevention in the context of chronic disease, or for poor quality sleep, lifestyle modifications related to light exposure, dietary habits, thermal regulation, and relaxation can each contribute to significant improvements in sleep’s therapeutic effects.

CLINICAL APPLICATIONS

1. Poor-quality sleep is associated with a variety of chronic conditions including cardiovascular disease, obesity, mood, and inflammatory disorders.
2. Assessment of sleep should be a cornerstone of every Lifestyle Medicine evaluation.
3. Sleep duration of less than six or more than nine hours per night is strongly associated with chronic disease.
4. Emerging therapies exist to help individuals achieve better quality or longer sleep, including decreased light exposure, improved dietary habits, thermoregulation, and mindfulness/cognitive behavioral therapy/relaxation techniques. Use of one or more of these modalities may be helpful in assisting individuals achieve better quality sleep and improving their health.

REFERENCES