

Treatment of Circadian Rhythm Sleep Disorders with Light

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Abstract

The human circadian system is normally synchronised with the solar day, insuring that alertness and performance peak during daytime hours and consolidated sleep occurs during the night. In circadian rhythm sleep disorders, the pattern of sleep-wake is misaligned with the patient's circadian system or the external environment, resulting in insomnia, fatigue, and deterioration in performance. Appropriately-timed exposure to bright light can reset the timing of sleep and wake to the desired times, and improve sleep quality and daytime alertness. The efficacy of bright light therapy, however, is dependent on the time-of-day of the circadian cycle that the light is administered. In this article, we examine the physiological basis for bright light therapy, and we discuss the application of light in the treatment of circadian rhythm sleep disorders including advanced and delayed sleep-phase disorder, free-running disorder (nonentrained type), shiftwork disorder and jet lag disorder. We review the laboratory and field studies which have established bright light therapy as an effective treatment for sleep-wake and circadian misalignment, and we also provide guidelines for the appropriate timing and safe use of bright light therapy.

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Introduction

In humans, the daily pattern of consolidated sleep and wake is strongly influenced by the timing of exposure to light and darkness. In the absence of environmental time cues, cycles of sleep-wake, physiology, and gene expression continue to exhibit a near-24-hour circadian rhythm (derived from the Latin phrase "circa diem", which means "about a day"). In mammals, circadian rhythms are generated endogenously by neurones in the suprachiasmatic nucleus (SCN) in the anterior hypothalamus.^{1,2} Daily exposure to light resets the phase of clock neurones in the SCN which, in turn, send multi-synaptic projections to sleep-wake centres in the brain to determine the timing of sleep and wake.³ Exposure to the 24-hour solar cycle normally insures that circadian rhythms of performance and alertness peak during daytime hours, and that a consolidated bout of sleep is achieved at night.⁴ In circadian rhythm sleep disorders, however, the sleep-wake cycle becomes misaligned with the circadian system or the external environment, resulting in insomnia, fatigue, and deterioration in performance and alertness.⁵ These symptoms can be treated by appropriately-timed exposure to artificial light, in order to align the circadian rhythms of sleep propensity and alertness with

the desired sleep and wake times of the patient.⁶ In this review, we discuss the physiological basis for light therapy and the efficacy of light as a treatment for circadian rhythm sleep disorders. We provide specific recommendations concerning the optimal timing of exposure to light and darkness, and we discuss safety concerns associated with light therapy.

Physiological Basis for Light Therapy

Light treatment of circadian rhythm sleep disorders is mediated exclusively by the activation of ocular photoreceptors.⁷ Specialised retinal ganglion cells which contain the blue light-sensitive photopigment melanopsin project directly to the circadian clock in the SCN.⁸⁻¹¹ Consistent with a primary role for melanopsin in mediating the effects of light therapy, clinical studies have established that exposure to bright monochromatic blue light (460 nm) is more effective than green light (555 nm, the peak of sensitivity of the three-cone photopic visual system) at phase-resetting the circadian system and suppressing night-time release of the pineal gland hormone melatonin.¹²⁻¹⁴ These studies suggest that blue-enriched light may be more effective than white light in the treatment of circadian

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rhythm sleep disorders, as remains to be tested.

The efficacy of light treatment for circadian rhythm sleep disorders is dependent on the dose of the light stimulus (i.e. the irradiance and duration of light). In laboratory studies, bright room light (>500 lux) elicits saturating responses for both phase shifting and suppression of the melatonin rhythm, if preceded by dim light (<15 lux).¹⁵ Consistent with these findings, in field studies, only exposure to bright artificial light (typically 2,500–10,000 lux) has been shown to improve sleep-wake quality and mood.⁶

The efficacy of light therapy in the treatment of circadian rhythm sleep disorders is strongly dependent on the time of day that light is administered. This is because the magnitude and direction of phase-resetting is dependent on the circadian phase at which the light stimulus occurs. This fundamental property of circadian oscillatory systems is summarised by the phase-response curve, a plot of the resetting response versus the circadian phase at which the light is given (Fig. 1). The circadian system is most sensitive to light during the biological night, during a time when most individuals are sleeping in darkness. Thus, light therapy is most effective in treating circadian misalignment if administered shortly after awakening, or shortly before bedtime. In human, exposure to light in the early biological night (near habitual bedtime) elicits phase delay shifts of the circadian system (i.e. shifting the circadian system westward), whereas exposure to light in the late biological night (near habitual

waketime) induces phase advance shifts (i.e. shifting the circadian system eastward).^{16–18} Thus, the appropriate timing of light therapy depends on whether the desired effect is a phase delay shift or a phase advance shift of the sleep-wake rhythm (Table 1).

Independent of the resetting effects of light on circadian rhythms, exposure to bright light acutely increases subjective ratings of alertness, as well as objective measures of arousal and performance.¹⁹ Recent studies indicate that blue light is more effective than green light at acutely enhancing alertness, improving reaction time, and inducing changes in the waking electroencephalogram (EEG) associated with arousal, suggesting that the melanopsin cells play an important role in promoting wake.²⁰ Given that exposure to bright light acutely reduces sleepiness and improves reaction time, light therapy may help counteract fatigue and decrements in performance associated with shiftwork and jet lag.

Delayed Sleep-Phase Disorder

In delayed sleep-phase (DSP) disorder, the sleep episode occurs much later than the desired sleep-wake times. Typically, patients with DSP experience sleep-onset insomnia and complain of chronic difficulty falling asleep until 2:00–6:00 a.m. (Fig. 2).²¹ Due to the delayed phase of the sleep-wake rhythm, patients with DSP also have difficulty waking up at the desired time in the morning. In

Table 1. Light Therapy for Circadian Rhythm Sleep Disorders

Sleep disorder	Symptoms	Desired outcome	Treatment
Advanced Sleep-Phase Syndrome	Early sleep-wake times, difficulty remaining awake in the evening, early morning awakenings during sleep	Later sleep-wake times, phase delay shift	Evening bright light therapy before bedtime, dim light after wake time
Delayed Sleep-Phase Syndrome	Late sleep-wake times, sleep onset insomnia, difficulty waking in morning	Earlier sleep-wake times, phase advance shift	Morning bright light therapy after wake time, dim light prior to bedtime
Non-24-Hour Sleep-Wake Disorder	Free-running sleep-wake cycle, periodic bouts of insomnia and daytime fatigue	Entrainment of sleep-wake cycle, phase advance shift	Morning bright light therapy after wake time, when sleep episode occurs during night
Shiftwork Sleep Disorder	Insomnia during daytime sleep, excessive sleepiness and fatigue during wake	Adaptation to shiftwork, large phase delay shift	Bright light therapy in evening/night, dim light after work, strict adherence to regular sleep-wake times
Jet Lag (eastward travel)	Sleep onset insomnia, difficulty waking in morning, daytime sleepiness and fatigue	Phase advance shift	Morning bright light therapy after wake time (home time), dim light prior to bedtime
Jet Lag (westward travel)	Early morning awakenings, daytime sleepiness and fatigue	Phase delay shift	Evening bright light therapy before bedtime (home time), dim light after wake time

For each sleep disorder, the primary symptoms and desired outcome are shown. The recommended timing of bright light therapy and exposure to dim light are provided for each circadian rhythm sleep disorder.

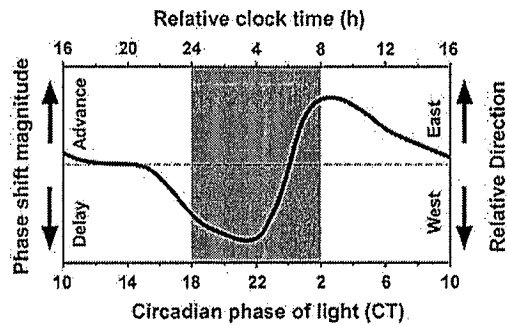


Fig. 1. Circadian phase-dependent resetting of the human circadian system. A phase-response curve (PRC) is shown for a hypothetical patient who sleeps from midnight until 8:00 a.m. The PRC illustrates that the circadian system is most sensitive to light during the night when sleep usually occurs (gray box). The black trace indicates the phase-resetting response to light. The relative magnitude and direction of phase-resetting are shown on the ordinate, and circadian time (i.e. internal biological time referenced to the body temperature minimum, TB_{min}) of the light therapy is indicated on the abscissa. Relative clock times are shown on the top. Exposure to light elicits phase delay shifts of circadian rhythms in the biological evening (shifting the circadian system westward), and phase advance shifts in the biological morning (shifting the circadian system eastward). By convention, in humans the minimum of the body temperature rhythm is defined as circadian time (CT) zero. Phase advance shifts on the ordinate are indicated by positive values, and phase delay shifts are indicated by negative values. The horizontal dashed line indicates a phase shift of zero.

some patients, symptoms of DSP are self-imposed due to social influences, schoolwork, or shiftwork, in which the individual chooses to stay awake late into the morning hours. In other patients, DSP is likely due to intrinsic factors such as a longer-than-average circadian period or a reduced capacity for phase advance shifts.²² Regardless of the underlying pathology for DSP, the desired outcome is an earlier sleep episode. Thus, a light-induced phase advance is desired, and light therapy should be administered in the morning, shortly after awakening. It follows that the patient should also avoid exposure to bright artificial light in the evening hours before bedtime, as this would result in an undesirable phase delay shift of the sleep-wake cycle. Applying these principles, a field-study in which DSP patients were administered early-morning light therapy (2,500 lux for 2 hours) coupled with restricted light in the evening, showed a phase advance of the body temperature rhythm, an earlier sleep onset, and increased morning alertness.²³ Similar findings have been reported in case studies, in which an earlier sleep-wake schedule was achieved with daily light therapy in the morning (30 min of 10,000 lux).⁶ Based on the positive findings in laboratory and field studies, the American Academy of Sleep Medicine has recognised the use of light therapy as a complementary or alternative treatment option for DSP.²⁴

Advanced Sleep-Phase Disorder

In advanced sleep-phase (ASP) disorder, the sleep episode occurs much earlier than the patient's desired sleep-wake

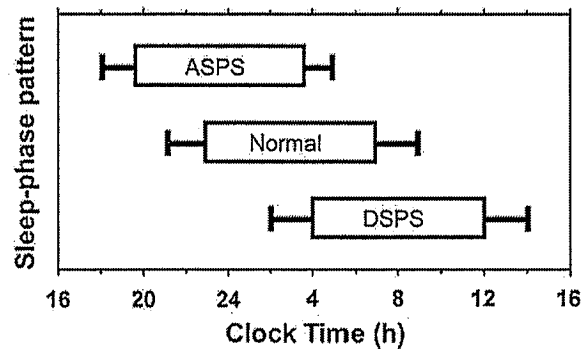


Fig. 2. Relative timing of sleep in patients with Advanced- and Delayed Sleep-Phase Disorder (ASP and DSP, respectively). The boxes and whiskers indicate the timing and range of sleep episodes for individuals with ASP, normal sleep-wake times, and DSP, as defined in The International Classification of Sleep Disorders. Adapted and modified from Reid et al., *Med Clin North Am*, 2005.⁵

times. Patients with ASP experience difficulty remaining awake in the evening and often complain of early morning awakenings during sleep. Typically, individuals presenting with ASP go to sleep between 6:00–8:00 p.m., and wake between 1:00–3:00 a.m., despite attempts to delay sleep-wake times to later hours (Fig. 2).²¹ The symptoms of ASP are thought to be derived from a short intrinsic circadian period,²⁵ or a reduced capacity for circadian phase delay shifts compared to phase advance shifts. Familial cases of ASP have an autosomal dominant mode of inheritance and have been linked to mutations in core clock genes that determine the period of the circadian cycle.^{25,26} Based on laboratory studies, in order to delay the timing of the circadian rhythm of sleep-wake in patients with ASP, daily light therapy should be administered in the evening, just prior to bedtime. In addition, the patient should avoid exposure to bright light in the morning hours after awakening, to avoid an undesirable phase advance shift of the sleep-wake cycle. In clinical practice, the efficacy of evening morning light therapy in the treatment of ASP has not been extensively investigated. In patients with early morning insomnia, exposure to 2 nights of evening light therapy (2,500 lux) improved sleep efficiency, increased total sleep time, and delayed the timing of body temperature and melatonin rhythms by about 2 hours.²⁷ As the prevalence of ASP increases with age, evening light therapy has been suggested for elderly patients to shift the timing of sleep and wake to later hours. In one study, exposure to bright light from 7:00–9:00 p.m. (4,000 lux) improved sleep efficiency, reducing the amount of night-time wakefulness by about an hour.²⁸ Collectively, these findings suggest that evening light therapy delays the sleep-wake cycle and improves night-time sleep in patients with ASP. Additional field studies are required, however, to clearly establish a beneficial role for light therapy in the treatment of ASP.

Free-Running Disorder (Nonentrained Type)

In patients with free-running disorder, the circadian rhythm of sleep-wake is desynchronised with the solar day. Rather, the sleep wake cycle drifts later each day, similar to the pattern observed in individuals housed in temporal-isolation without periodic time cues.²⁹ Thus, across many days the circadian rhythms of sleep propensity and alertness drift in and out of phase with the desired social hours for sleep and wake. This results in periodic bouts of insomnia and daytime fatigue during times when the circadian peak of alertness occurs at night and the circadian drive for sleep peaks during the daytime. Free-running disorder is almost exclusively reported in blind individuals with damage to the optic nerve, in which case light therapy is not a viable treatment option.³⁰ In blind patients without circadian photoreception, daily administration of melatonin in the biological evening has been shown to synchronise the circadian system to the 24-hour day.^{31,32} In normally-sighted individuals, free-running disorder is very rare and has been attributed to disruption of the light entrainment pathway (e.g. a tumour in the SCN region), reduced sensitivity of the circadian system to light, or insufficient exposure to light during the phase advance region of the phase-response curve, resulting in failure to entrain to the solar day.³³⁻³⁵ In the few cases of free-running disorder that have been reported in sighted individuals, light therapy has been administered daily in the morning hours after sleep (when sleep is in phase with the night cycle) to stably entrain the sleep-wake cycle through phase advance shifts of the circadian clock.^{36,37}

Irregular Sleep-Wake Rhythm

In patients with irregular sleep-wake rhythm, a circadian rhythm of sleep-wake cannot be clearly defined. Rather, the pattern of sleep-wake is disorganised such that sleep and wake periods occur variably throughout the 24-hour day, with frequent napping, insomnia, and excessive daytime sleepiness. Irregular sleep-wake rhythm is thought to derive from neurologic dysfunction (e.g. dementia, mental retardation, or brain injury), or from inadequate exposure to periodic synchronisers such as light, physical activity, or social interactions.⁵ Hence, irregular sleep-wake rhythm is thought to be most prevalent in the institutionalised elderly and in patients with dementia, who are often exposed to irregular and/or dim lighting and unstructured social schedules. Given that the distribution and quality of sleep have a profound impact on human physiology, performance, and mood, in future studies it will be important to determine whether regularly scheduled exposure to natural light or artificial light is sufficient to consolidate the circadian cycle of sleep-wake in patients with irregular sleep-wake rhythm.

Shift Work Disorder

In shift work disorder, patients complain of insomnia during daytime sleep and excessive sleepiness during the night shift, as a result of performing shift work during the habitual hours of sleep. These symptoms result from the inability of many shift workers to adapt the timing of their circadian system to the imposed work schedule.³⁸ Thus, in shift workers who are unable to adapt, the circadian rhythm of sleep propensity peaks during the work shift, resulting in fatigue, an increased risk of work-related accidents, and a higher rate of single-vehicle car crashes on the drive home after work.³⁹⁻⁴¹ In addition, the circadian rhythm of alertness peaks during the daytime, resulting in insomnia during daytime sleep and a reduction in total sleep time. The sleep loss and circadian misalignment associated with shift work are thought to contribute to the increased risk of developing gastrointestinal disorders, metabolic syndrome, diabetes, heart disease, and cancer in the shift work population.⁴²⁻⁴⁷

Complete adaptation to night shift work requires strict adherence to regular sleep and wake times, exposure to adequately bright lighting during work shifts, and darkness during scheduled sleep. This is difficult for many shift workers, who attempt to adopt a normal daytime schedule on days off from work, and who are often exposed to bright light in the morning hours after work, resulting in a counterproductive phase advance shift of the circadian system.³⁸ In simulated shiftwork studies, in which research subjects were exposed to bright light during the work shift (approximately 10,000 lux for 7.5 hours, 4 consecutive days) and sleep in darkness at home, circadian rhythms of body temperature, cortisol, and subjective alertness realigned with the imposed night shift schedule, whereas exposure to room light did not result in adaptation to shiftwork.⁴⁸ Furthermore, subjects who were exposed to bright artificial light during the simulated work shift reported 2 more hours of daytime sleep, as compared to subjects exposed to ordinary room light. In a later study, it was shown that even in the absence of exposure to bright light at night, subjects who adhere to a regular sleep-wake schedule show faster adaptation to shiftwork than do individuals with variable sleep onset times.⁴⁹ Subjects who received bright light therapy and were able to maintain a regular sleep-wake schedule exhibited the strongest adaptation to shiftwork, indicating an additive effect of these strategies. In other simulated shift work and field studies, exposure to bright evening light (approximately 5,000 lux) and dim morning light (subjects wore dark goggles after the end of the night shift), induced phase delays of the circadian system, which is considered beneficial for adaptation to shiftwork.^{50,51} In 2 independent field studies, night shift nurses were exposed to bright artificial light in the evening (approximately 5,000 lux for

4 hours or approximately 3,000 lux for 6 hours) and to reduced outdoor morning light after the end of the work shift (via sunglasses or tinted goggles).^{52,53} After daily administration of this lighting regimen, nurses who were exposed to bright light during work shifts reported increased alertness at night and increased amounts of daytime sleep,⁵³ and the circadian rhythms of melatonin and body temperature shifted by greater than 9 hours,⁵² demonstrating physiological adaptation to the night shift schedule. In contrast, exposure to room light during the work shift and morning bright light after work did not result in adaptation to nightshift work. Collectively, these studies show that shift work disorder can be treated by appropriately timed exposure to light and darkness, and regularly scheduled sleep.

Jet Lag Disorder

Jet lag disorder occurs after rapid transmeridian travel and is due to a temporary misalignment between the timing of the internal circadian clock, relative to the pattern of light and darkness in the new time zone. Jet lag is characterised by insomnia during desired sleep times, excessive sleepiness during the waking day, and somatic symptoms such as gastrointestinal discomfort.²¹ The severity of jet lag is dependent on the number of time zones crossed, the direction of the flight (eastward versus westward), and the quality and amount of sleep obtained in-transit.⁵⁴ Although jet lag is considered a simple inconvenience for most travellers, it can be a chronic and deleterious condition for pilots, flight crew, military personnel, and frequent business travellers. Following travel eastward, individuals most often experience difficulty falling asleep at the desired clock time, resulting in an increased number of awakenings during the early part of the sleep episode. In contrast, following travel westward, individuals often experience an increased number of awakenings in the early morning. Based on the fundamental property of circadian phase-dependent resetting of circadian rhythms (see above), appropriately-timed exposure to light can reset the circadian system in the desired direction for adaptation to the new time zone.¹⁷ For travel eastward, a phase advance shift is required for re-entrainment, in which exposure to bright light should be timed in the early morning (home time), and dim light in the hours preceding normal bedtime. For travel westward, a phase delay shift of the circadian system is required for realignment, in which exposure to bright light should be timed in the evening hours before sleep onset (home time), and dim light in the hours after awakening.⁵⁵ To accelerate adaptation to the new time zone, the exact timing of exposure to light and darkness is dependent on the individual's circadian phase, and the direction and number of time zones to be travelled. As such, computer programs, travel tables, and website calculators have been

developed with guidelines for light treatment of jet lag.^{54,56} Although there have been numerous laboratory-based studies on the resetting effects of light on the sleep-wake rhythm, there have been relatively few field studies that have focused on light therapy for jet lag. In one study, individuals who received bright light therapy following eastward travel from Tokyo to San Francisco showed higher sleep efficiency compared to individuals exposed to dim light, as assessed by polysomnography.⁵⁷ In another study in which subjects travelled westward from Zurich to New York City, exposure to bright light therapy for 2 consecutive evenings after arrival resulted in a larger phase delay of the circadian system (approximately one hour) compared to exposure to dim light, indicating accelerated physiological adaptation to the new time zone, but there were no detectable improvements in performance, alertness, and sleep efficiency.⁵⁸ It should be noted that sometimes re-adaptation to the new time zone is not desirable, such as for flight personnel travelling east to west, and then returning eastward only days later. Thus, to accelerate or decelerate re-entrainment following transmeridian travel, exposure to light and darkness must be timed appropriately to elicit phase delay shifts or phase advance shifts of the circadian system, as desired.

Light Therapy Considerations

Currently, there are no standard guidelines governing the application of light therapy for the treatment of circadian rhythm sleep disorders. An attempt has been made, however, to establish basic safety standards and recommendations regarding the use of light therapy devices.⁶ These guidelines are largely based on the application of bright light therapy in the treatment of Seasonal Affective Disorder (SAD), in which patients experience recurrent depressive symptoms that vary with seasonal changes in day length. Morning bright light therapy is most effective at treating seasonal depression, suggesting that SAD may have a circadian aetiology in which phase advance shifts and extension of the natural photoperiod are beneficial for treating depression.⁵⁹ Based on laboratory and field studies, light therapy should be sufficiently bright (2,000–10,000 lux) to elicit a clinically significant response, but also short enough in duration (<2 hours) to insure patient compliance.⁶ Recent studies suggest that blue light is most effective at resetting circadian rhythms, suppressing night-time melatonin, and enhancing performance, as compared to longer-wavelength light.^{12–14,20} Thus, white light therapy that is now prescribed for treatment of circadian rhythm sleep disorders and SAD may soon be replaced by light therapy devices that emit blue-enriched light. Currently, there are several ongoing clinical trials testing whether blue-enriched light is better than conventional white light sources at resetting circadian rhythms, suppressing melatonin, and increasing alertness.

In the clinical setting, if a patient is taking photosensitising medications or has a psychiatric condition, caution should be exercised in prescribing light therapy, and the patient's behaviour should be monitored closely.^{6,60} Medications that are known to photosensitise the skin and/or retinal tissues include antipsychotics (e.g. phenothiazines), psoralen (used in the treatment of psoriasis), antiarrhythmic agents (e.g. amiodarone), porphyrin drugs used in the treatment of skin diseases, antirheumatic drugs, St. John's Wort, antimalarial drugs, tetracycline, tricyclic antidepressants (e.g. imipramine and desipramine), sulfonamide-based drugs, and diuretic drugs (for more information, visit the Center for Environmental Therapeutics website, www.cet.org). An ophthalmologist and/or dermatologist should be consulted with if there is any doubt regarding the safety of administering light therapy with patient medications. It is recommended that all new patients have an eye exam prior to commencing light therapy to confirm normal ocular health. Retinopathy is considered an absolute contraindication for bright light therapy, and patients with glaucoma and cataracts may also be at risk for ocular damage.⁶ In response to bright light therapy, some patients report visual discomfort including eyestrain and glare, headache, or nausea, in which case the treatment regimen may need to be modified or discontinued.

Recently, a wide range of commercially available light therapy devices have entered the market place including white light boxes, light visors, dawn simulators, and coloured light boxes (e.g. blue LED boxes). Unfortunately, many of these devices have not been clinically tested for their efficacy or safety. It is therefore important to select a light therapy device that has tested positively in one or more peer-reviewed clinical research studies. Importantly, light therapy devices must provide for adequate filtering of UV and infrared light, so as to avoid ocular damage, and the spectral emission of the light source should be provided by the manufacturer. The light source must be bright enough such that the treatment is effective (e.g. 10,000 lux at approximately one foot from the device), and also large enough such that the eyes remain in the therapeutic range of the light even with small movements of the head. If the light box is positioned to minimise glare (e.g. tilted downward toward the subject's eyes), activities such as reading are possible, although this reduces the amount of light reaching the retina and may reduce the efficacy of light treatment. Light therapy devices that use fluorescent or LED bulbs should have a diffuser screen that filters UV light (i.e. naked bulbs should be avoided), and ordinary incandescent lamps should not be used for light therapy, as they emit high levels of infrared light (nearly 90% of total output) that may cause damage to the lens, cornea, and retina.⁶ Home construction of light boxes is highly

discouraged, as their use could jeopardise the ocular health of the patient. For reference, the Center for Environmental Therapeutics website (www.cet.org) provides specific guidelines for selection of light therapy devices, and an "Ask the Doctor" forum for clinician and patient questions regarding the proper application of light therapy.

Given that light therapy devices may not be readily available for patients and practitioners, appropriately-timed exposure to sunlight may also be helpful in treating some circadian rhythm sleep disorders. A major advantage of using a light therapy device is that the illuminance can be kept constant, whereas natural lighting may vary day-to-day in an unpredictable manner (e.g. sunny versus rainy weather). Nonetheless, if a light box is not available for treatment, the illuminance measured outside at dusk or dawn on a clear day is similar to the intensity of artificial light generated by many commercially-available light therapy devices (about 10,000 lux). Thus, in patients with DSP disorder, taking a morning walk immediately after wake time may be beneficial, as exposure to early sunlight would elicit a phase advance shift of the circadian system (Fig. 1). In some situations, exposure to sunlight could also interfere with the desired clinical outcome, however, such as in shift workers who are exposed to bright light on their way home from work, in which case sunglasses may be worn to reduce light input to the retina.^{38,51} In patients whose circadian system is aligned with the solar cycle such that sleep occurs during night-time, exposure to natural or artificial light during the middle of the day is unlikely to interfere with bright light therapy administered in the early morning or late evening, because the circadian system is relatively insensitive to light during the biological daytime (Fig. 1).

Conclusions

Bright light therapy for circadian rhythm sleep disorders is an effective treatment option for sleep-wake disturbances. Appropriately-timed exposure to bright light can shift the sleep-wake cycle to earlier or later times, in order to correct for misalignment between the circadian system and the desired sleep-wake schedule. Laboratory studies have established that the human circadian system is exquisitely sensitive to light, and that the efficacy of light in resetting circadian rhythms is determined by the dose, spectral content, and time-of-day that the light is administered. In field studies and in the clinical setting, these principles have been applied successfully to treat circadian rhythm sleep disorders. In future studies, it will be important to improve the efficacy and delivery of light therapy, and to establish standards of practice for the application of light therapy in the treatment of circadian rhythm sleep disorders.

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