Review

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Review

Circadian-Based Sleep Interventions in Clinical Applications: A Narrative Review

Running title: Circadian interventions for sleep

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Abstract

Circadian misalignment, whether from external factors (shift work, jetlag, irregular schedules, or evening screen exposure) or internal factors (chronotype, circadian rhythm disorders), extends beyond sleep disruption to affect immune, cardiovascular, metabolic, and mental health. Despite growing evidence for their efficacy, circadian-based strategies such as timed light exposure, structured activity schedules, meal timing, and circadian psychoeducation, are not consistently integrated into behavioral sleep interventions, and standardized protocols remain limited. While Cognitive Behavioral Therapy for Insomnia (CBT-I) remains standard treatment for insomnia, it does not directly address biological timing. Recent evidence demonstrates that combining CBT-I with circadian rhythm support produces superior outcomes compared to either approach alone. However, gaps remain regarding optimal intervention timing, personalized protocols based on chronotype, long-term efficacy, and implementation in diverse clinical settings. This narrative review synthesizes current evidence on integrating circadian interventions with CBT-I in different clinical applications, and reviews novel assessment tools such as chronotype questionnaires and wearable devices that enable identification of circadian patterns and personalized interventions. By bridging behavioral therapy with circadian-based strategies, clinicians can move beyond symptom management to address underlying causes of sleep disruption, offering a more comprehensive framework for improving sleep and well-being.

Keywords: circadian interventions; insomnia; sleep health; cognitive behavioral therapy for insomnia (CBT-I); circadian misalignment

1. Introduction

Circadian rhythms are endogenous, near-24-hour cycles that regulate a wide array of physiological, cognitive, and behavioral processes in humans (1). Circadian alignment refers to the synchronization of internal biological cycles with external cues like light, meals, and activity (2). This alignment promotes restorative sleep and supports cognitive, emotional, and physical well-being, and is orchestrated by a central pacemaker located in the suprachiasmatic nucleus (SCN) of the hypothalamus (1). Circadian alignment supports consolidated sleep, stable mood, and optimal daytime functioning (2). In contrast, circadian misalignment occurs when there is a discrepancy between internal rhythms and environmental or social demands (2), including external factors like rotating night-shift work, frequent international travel, or irregular schedules, behavioral patterns like extended evening screen use and inconsistent bedtimes, or intrinsic factors like delayed or advanced sleep phase (3). The prevalence of circadian misalignment has grown due to changing lifestyles and technological advances, such as around-the-clock work schedules, international communication, and widespread evening exposure to artificial light, all of which have left many

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individuals “out of sync” with their biology. Adolescents are especially vulnerable to circadian misalignment because of developmental shifts toward later sleep timing, compounded by academic and social pressures. Adults working rotating or permanent night shifts often experience chronic misalignment, which elevates the risk of psychiatric and cardiometabolic conditions. Even among the general population, inconsistent sleep and eating habits frequently contribute to circadian misalignment (2). While recent reviews have examined the relationship between sleep, circadian rhythms, and mental health (4), or potential adjunct or alternative treatments to behavioral interventions for insomnia (5), this narrative review aims to summarize and translate emerging circadian research into practical, implementation-ready tools for therapists and behavioral sleep clinicians, providing updated evidence on emerging digital modalities and population-specific applications.

The effects of circadian misalignment extend well beyond insufficient sleep (6) . Many individuals report insomnia symptoms such as difficulty falling or staying asleep despite adequate opportunity for rest. They report daytime fatigue, reduced alertness, and impaired cognitive function, with implications for productivity, safety, and academic performance (7). Prolonged circadian misalignment has also been linked to broader systemic effects, including immune dysfunction, obesity, cardiovascular disease, and mood disturbances including anxiety and depression (2, 6, 8). Thus, understanding circadian biology is essential for behavioral sleep clinicians, not only to improve sleep, but also to support overall health. While Cognitive Behavioral Therapy for Insomnia (CBT-I) remains the gold standard treatment for insomnia (9), its focus on behavioral and cognitive strategies does not fully address circadian biological timing. Recent randomized controlled trials (RCTs) showed that combining CBT-I with circadian rhythm support (morning bright light, scheduled activity, evening body warming) produced enhanced long-term efficacy and unique neurobiological effects, superior to either modality alone (10, 11). However, standardized protocols for integrating circadian interventions with CBT-I remain limited in routine clinical practice.

In this narrative review, we examined current evidence on integrating circadian-based approaches such as timed light exposure, structured activity, scheduled meals, and psychoeducation with standardized behavioral interventions, to offer a more comprehensive framework for treatment, and reviewed assessment tools like chronotype questionnaires and wearable devices that enable therapists to better identify circadian patterns and tailor interventions. By bridging behavioral therapy with circadian science, clinicians can move beyond managing symptoms to address underlying causes of sleep disruption, tailor interventions, and improve adherence. Integrated approaches position circadian alignment as central to modern behavioral sleep medicine.

Methods for Narrative Review

We conducted a targeted narrative review (June 2012–November 2025) using PubMed, Google Scholar, and guideline repositories (e.g. UK’s National Institute for Health and Care Excellence, NICE), focusing on circadian mechanisms, light/exercise/meal timing, melatonin, and digital CBT-I (dCBT-I), and prioritizing on recent RCTs, systematic reviews, meta-analyses, and clinical guidelines. Given the narrative design, we did not perform systematic risk-of-bias assessments or meta-analysis. Evidence quality is indicated by study design descriptors.

2. Mechanisms of Circadian Regulation

Circadian rhythms are maintained by an intricate biological clock centered on the suprachiasmatic nucleus (SCN), which serves as the body’s master pacemaker by generating near-24-hour rhythmic activity and synchronizing internal timing cues with the external light–dark cycle (12). Proper circadian alignment supports daytime wakefulness and nighttime sleep, as the SCN regulates melatonin release from the pineal gland, which rises in the evening as light fades and falls in the morning with light exposure (13). Through these orchestrated processes, the SCN modulates sleep-wake cycles, hormone secretion, body temperature fluctuations, and autonomic activity (13).

Beyond the SCN, circadian rhythm is also coordinated by peripheral oscillators (circadian clock) distributed across organs and tissues, such as the liver, heart, pancreas, and skeletal muscle (14). While these peripheral oscillators can maintain short-term rhythms on their own, they rely on the SCN for long-term circadian alignment. These peripheral oscillators also regulate metabolic processes, cardiovascular function, and energy balance throughout the day (14-16), thus disruptions between central and peripheral oscillators driven by external or internal factors can compromise bodily health, highlighting their relevance for clinical assessment and intervention.

Additionally, the circadian system is highly sensitive to external cues, or zeitgebers, which provide temporal information to both central and peripheral oscillators (17). Light is the strongest zeitgeber, with morning light advancing the circadian phase and evening light delaying it, making light management a primary method for resetting rhythms (18, 19). Temperature, scheduled meals, and exercise also serve as secondary zeitgebers, reinforcing circadian alignment or causing misalignment when inconsistent (20-23). Individual differences in circadian timing also exist, reflected as chronotypes or natural tendencies toward earlier or later sleep and waking patterns (24). For example, "morning types" have an inclination for earlier sleep and waking times, whereas "evening types" lean toward later times. Such inclinations have both genetic and environmental origins (24) and should be considered during circadian interventions. Another form of circadian variation involves phase shifts, where the circadian rhythms become delayed or advanced relative to the desired timing (25). Jet lag is a typical example of phase delay where the resulting misalignment gives rise to symptoms like fatigue, disrupted sleep, and gastrointestinal discomfort (26). These shifts can gradually realign through exposure to environmental zeitgebers, primarily light and meal timing (26). However, the misalignment of phase shifts tends to be more persistent among shift workers, as their work schedules often oppose the environmental cues, making realignment based on these cues less plausible (27). Together, these environmental anchors coordinate biological rhythms within day-to-day life (**Table 1**).

Table 1. Key zeitgebers and their influences on circadian rhythm.

Zeitgeber	**Primary Influence**	**Strength of Effect**	**Clinical Relevance**
Light	Synchronizes the SCN; regulates melatonin secretion and sleep–wake cycle	Very Strong	Bright morning light advances circadian phase; evening light delays sleep. Used in light therapy for insomnia, delayed sleep phase disorder, and shift work adjustment. (18, 19)
Scheduled Meals	Entrains peripheral clocks (liver, digestive system, pancreas)	Strong	Consistent meal timing supports metabolic health; late-night eating disrupts circadian alignment and increases risk of metabolic disorders. (21)
Structured Activity	Shifts circadian phase through energy expenditure and hormonal signaling	Moderate	Morning/afternoon exercise can advance rhythms; late-night activity can delay sleep onset. Applied in lifestyle counseling. (22, 23)

3. Evidence-Based Circadian Interventions

Understanding the biological mechanisms of circadian rhythms provides a framework to translate evidence into practice, moving beyond symptom management to apply strategies that restore circadian alignment in daily routines. For example, circadian science can inform the timing of evidence-based behavioral interventions including light-based therapies, behavioral and environmental modifications, scheduled meal approaches, and emerging modalities including pharmacological support and digital technologies. Collectively, these interventions provide a set of practical tools for addressing circadian misalignment in individuals.

3.1. Light-Based Interventions

The strongest zeitgeber of the circadian rhythm is light. Light-based interventions manipulate the timing, intensity, duration, and spectrum of visible light to facilitate circadian alignment. Light exposure, especially blue-enriched short-wavelength light, has a direct effect on the SCN and regulates secretion of melatonin (28). Morning bright light therapy at 5,000 to 10,000 lux during the first hour of waking can advance circadian phase, particularly in delayed sleep-wake phase disorders and in late-chronotype adolescents (29, 30). Conversely, minimizing bright light in late afternoon/evening helps prevent circadian delays in adolescents (31). Tools such as light boxes, wearable blue-light blocking glasses, and dawn simulators can also facilitate incorporation of light exposure into daily routines, offering flexibility for individuals who are unable to control ambient light conditions. Recent systematic review and meta-analysis of 22 studies (including 15 RCTs) involving more than 700 participants showed that light therapy significantly improved both subjective sleep quality and objective sleep parameters including total sleep time and wake after sleep onset compared to controls, supporting clinical utility of light therapy for insomnia (32, 33). However, effect sizes were modest and optimal parameters (intensity, timing, duration) have not been defined for different insomnia phenotypes.

3.2. Behavioral Strategies

While light-based therapy remains the primary modality for circadian intervention, structured daily behaviors adjustments are critical for reinforcing circadian alignment. Consistent sleep–wake schedules, wind-down routines, and morning rituals can help strengthen entrainment by pairing biological rhythms with predictable behavioral cues (2). Exercise timing may also modestly influence circadian phase. For example, in a controlled trial with primarily young, healthy adults, morning exercise induced phase advances of approximately 0.6 hours, while evening exercise showed minimal phase-shifting effects; however, substantial variability was observed driven by chronotype, baseline circadian phase, and exercise intensity (34). Therefore, individuals' chronotype may be considered to help guide tailored exercise timing, although the clinical significance of circadian phase-shifting for sleep disorders remains uncertain and requires further study (35). Accordingly, current evidence-based guidance continues to emphasize general sleep hygiene practices, including avoiding vigorous late-night exercise (36).

3.3. Scheduled Meals & Entrainment

Meal timing may influence peripheral circadian clocks, particularly in metabolic organs like the liver and pancreas (21). Observational data suggested associations between later meal timing and circadian phase delays, though a recent scoping review found limited interventional evidence that chrononutrition strategies improved sleep quality, with only 2 of 9 studies demonstrating benefit (37). While consistent meal timing may support metabolic regulation and nocturnal sleep consolidation in some individuals (38), the independent contribution of meal timing to sleep outcomes (separate from caloric intake, composition, and other lifestyle factors) warrants further study. The growing field of chrononutrition emphasizes that when we eat, in addition to what we eat, represents an emerging area of metabolic and circadian research requiring stronger evidence.

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3.4. Pharmacological Approaches

Exogenous melatonin and melatonin agonists can be effective for circadian phase shifting in specific circadian rhythm sleep-wake disorders (e.g. delayed sleep-wake phase disorder, jet lag) when correctly timed (39). When taken in the early evening, these agents can advance the circadian phase and facilitate earlier sleep onset in individuals with delayed sleep timing or travelers adjusting to eastward time-zone changes (40). When paired with behavioral strategies such as fixed sleep–wake schedules and strategically timed light exposure, these pharmacological approaches can help address the underlying circadian misalignment and stabilize circadian rhythm.

3.5. Digital Tools

Digital CBT-I (dCBT-I) has demonstrated efficacy for the treatment of insomnia in multiple meta-analyses, with moderate-to-large effect sizes on insomnia severity compared to control conditions (41). A large-scale systematic review and meta-analysis of 29 RCTs involving more than 9,000 participants have found that fully automated dCBT-I demonstrated moderate to large effects on improving insomnia severity, though less effective than therapist-assisted CBT-I (42). The United Kingdom's National Institute for Health and Care Excellence (NICE) recommends certain dCBT-I platforms (e.g. Sleepio) as cost-effective options for insomnia in primary care when face-to-face therapy is unavailable (43). However, real-world implementation barriers exist, including variable insurance coverage, low completion rates for digital delivery (typically 40-60%), and the need for digital literacy (44). While FDA-authorized prescription digital therapeutics for insomnia exist (e.g. Somryst), commercial availability and reimbursement pathways remain limited (45).

In addition, wearables and smartphone-based sleep tracking tools offer accessible ways to characterize activity-rest cycles, sleep-wake patterns, and light exposure in naturalistic settings. Actigraphy remains the most clinically validated tool for objective sleep-wake assessment (46), yet consumer wearable devices including smartwatches, rings, and embedded phone sensors can capture multiple relevant parameters including activity-rest cycles, sleep-wake timing, heart rate variability, and (in some models) light exposure, that can inform circadian phase assessment (47). Recent work in digital phenotyping also suggests that smartphone interaction patterns may serve as proxies for circadian rhythms and insomnia severity, offering a low-burden alternative when formal monitoring is not feasible (48). Increasingly, devices equipped with ambient light sensors can be used by apps (e.g. Entrain, Timeshifter) that employ algorithms to suggest the best light exposure for an individual to support behavioral guidance in promoting circadian alignment (49). Despite these promises, limitations remain for these wearables and devices. Recent validation studies demonstrated that consumer wearables systematically overestimate total sleep time by misclassifying wake periods, and accuracy is poorer in individuals with fragmented sleep or low sleep efficiency, i.e. those who are most likely to seek clinical assessment (50, 51). Sleep state estimates also varied across manufacturers and firmware versions, with most devices underestimating wake after sleep onset by more than 30 minutes compared to polysomnography (50). Accuracy also varies by use characteristics include user skin tone, device placement, and environmental context (52). Therefore, while these devices may be useful adjuncts for tracking longitudinal patterns, caution needs to be taken for clinical interpretation.

Lastly, just-in-time adaptive interventions (JITAI) extend digital care by leveraging smartphone or wearables to collect real-time data and deliver behavioral interventions during moments of heightened clinical relevance such as late-evening screen exposure, prolonged wakefulness in bed, or insufficient morning light. JITAI can be designed to detect risk patterns and provide timely cues to reinforce sleep-promoting behaviors outside the clinic. These approaches serve as promising adjuncts to structured therapies like CBT-I, providing day-to-day reinforcement of sleep-promoting habits and supporting adherence and long-term maintenance of circadian-aligned behaviors (53). Optimization of JITAIs often relies on microrandomized trial (MRT) designs, where many small decision points (e.g. nightly wind-down cues or morning light reminders) are randomized. MRTs allow clinicians to determine when, for whom, and under what conditions these digital nudges can be most effective, ultimately informing personalized intervention rules that can be integrated into routine care pathways. Refining these contextual triggers could identify the most appropriate clinical use-cases for JITAIs within circadian-focused practice. However, their full clinical value is still being established through ongoing validation and development of clear use-cases (54).

Overall, integrating digital tools with behavioral strategies show promises in improving adherence and therapeutic outcomes (**Table 2**). However, further research is needed to determine best practices for combining modalities in different clinical populations.

Table 2. Digital tools and wearables with clinical utility.

Tool	Examples	Core Features	Key Findings	Level of Evidence	Refs
Digital CBT-I (dCBT-I)	*Sleepio, SHUTi, Somryst*	Automated CBT-I modules with feedback adapted to user progress.	Improves insomnia severity and sleep efficiency vs control; effects slightly smaller than therapist CBT-I but supported by multiple RCTs and recommended when in-person therapy is unavailable.	Moderate-Strong	(41, 55, 56)
Consumer Sleep Wearables	*Oura Ring, Fitbit, Apple Watch*	Tracks sleep timing, physiology, and activity over time.	Aids self-monitoring and behavioral adherence; reasonable accuracy for sleep duration but variable for staging.	Moderate	(47)
Light Timing Apps	*Entrain, Timeshifter*	Algorithms guide timing/duration of light exposure.	Used for circadian realignment in shift-work or jet lag; few controlled trials.	Preliminary	(57)
Digital Phenotyping	*mindLAMP, passive smartphone data*	Infers circadian patterns from passive phone-use patterns.	Enables low-burden circadian pattern inferences; clinical translation is early-stage.	Emerging	(48, 58, 59)
Just-in-Time Adaptive Interventions (JITAI)	*SleepWell, ecological momentary assessment (EMA) methods*	Real-time sensing or EMA triggers adaptive behavioral prompts.	Supports adherence to sleep-promoting behaviors; efficacy under investigation.	Emerging	(53, 60, 61)

4. Therapeutic Integration

In clinical practice, therapists often encounter clients whose sleep difficulties persist despite following standard CBT-I protocols. Circadian science provides tools that can fill this gap by addressing the biological timing of sleep. Integrating circadian-guided strategies by combining circadian psychoeducation, various assessment tools, and adherence strategies with CBT-I expands therapists' toolkit and helps move beyond symptom management, allowing clinicians to target both behavioral patterns and underlying circadian misalignment, ultimately improving treatment outcomes. The following section dissects each of these strategies individually to guide structured implementation in practice.

4.1. Circadian Psychoeducation

Psychoeducation provides the foundation for integrative care. Because many individuals are unfamiliar with circadian regulation of sleep-wake cycles, alertness, mood, and metabolism, clinicians can define the biological clock in accessible terms and use visual aids to illustrate how light, food, and activity entrain internal rhythms to the external world (62, 63). For example, brief diagrams depicting morning light as a zeitgeber that advances circadian phase can be used to highlight circadian alignment as a core therapeutic target. Clinicians should also emphasize practical behaviors like morning bright light exposure and regular sleep-wake schedules, that although modest in daily effort, cumulatively support long-term health. Strategic communication of these ideas can improve motivation and adherence and fosters sustained self-management of sleep (64).

4.2. Assessment Tools

Proper assessment is essential for tailoring interventions to the biological and behavioral rhythms of the individual. Several well-established tools are available to clinicians for evaluating circadian propensities and sleep quality. For example, the Morningness-Eveningness Questionnaire (MEQ) is a validated tool for assessing chronotype, identifying whether an individual has a morning, evening, or intermediate preference (65). The Munich ChronoType Questionnaire (MCTQ) extends this by assessing actual sleep-wake patterns on workdays and free days, to measure how external (work, school) schedules may conflict with an individual's natural chronotype (66). This knowledge may be leveraged to implement personalized interventions that resonate with the individual's natural preferences, as well as real-world sleep patterns, offering insights on how external schedules influence the quality and timing of sleep, which could help improve sleep and daily functioning. The Pittsburgh Sleep Quality Index (PSQI) is another popular tool that can be used to assess subjective sleep quality and disturbances, capturing subjective sleep experiences that may not be evident in objective measurements, including perceptions of sleep quality, latency, duration, efficiency, and daytime dysfunction (67). Together, these assessment tools enable clinicians to characterize individual circadian patterns and tailor recommendations regarding light exposure, activity level and timing, and meal schedules to support entrainment and align with individuals' lifestyles and health goals.

4.3. Adherence Strategies

Adherence remains the largest challenge for behavioral sleep medicine. Circadian-based treatments, such as strict schedules of light exposure or meal timing changes, require continued effort. Without strategies for maintaining engagement, individuals may fall back into old habits. Various adherence strategies can help encourage and maintain improvements in sleep health by addressing both the psychological and practical components of treatment adherence. First, motivational interviewing (MI) enables individuals to use their intrinsic motivation by investigating their values and goals, which makes them more likely to commit and adhere to treatment protocols (68). For example, clinicians might ask, "How important is it for you to wake up feeling refreshed?" or "What benefits might a consistent sleep schedule bring to your daily life?" Such questions foster autonomy and encourage active participation in health behavior change. Another effective tool is habit monitoring, where individuals use sleep diaries, smartphone apps for sleep or habit-tracking (e.g. Sleep Cycle), or visual progress charts to track adherence to and patterns (69). These instruments provide instant feedback and highlight progress over time, promoting positive behavior by helping individuals see improvements, stay focused on their goals, and maintain motivation and ownership of healthy sleep behaviors. Lastly, positive reinforcement strategies, such as acknowledging weekly adherence milestones (e.g. completing 5 days of morning light exposure) or using self-reward systems, enhance motivation and support sustained behavior change. Collaborative goal-setting with graduated difficulty helps maintain engagement over time (70).

4.4. Integration with CBT-I

Traditional CBT-I consists of stimulus control, sleep restriction, cognitive restructuring, and relaxation training (71). While these methods can effectively alleviate insomnia, they do not directly address underlying circadian misalignment. Recent evidence suggests increased efficacy when combining CBT-I with circadian rhythm support interventions. A recent randomized trial (n=122) found that CBT-I combined with circadian rhythm support (morning bright light, scheduled physical activity, evening body warming) produced superior long-term outcomes compared to either intervention alone, with unique effects on emotional brain responsiveness associated with reduced depression risk (72). The combined intervention showed the strongest sustained improvements in both sleep and mood at 1-year follow-up (72). Another recent pilot study (n=101) tested dCBT-I with emphasis on circadian biology education (i-Sleep & BioClock) among university students and demonstrated feasibility and acceptability, though completion rates remained low (13%), highlighting challenges with engagement common to digital interventions (73). To effectively integrate circadian alignment interventions with CBT-I, clinicians will begin with determining the individual's chronotype and the predictability of sleep-wake cycles. After this, clinicians can identify the triggers of circadian misalignment, such as inconsistent light exposure, disrupted meal schedules, or irregular daily routines. Interventions based on circadian timing may include bright light exposure in the morning, avoidance of blue light in the evening, and scheduling of activities and meals. Adherence may be supported by supervision with feedback, using diaries, wearables, or digital devices to inform the changes and track progress. Lastly, key elements of CBT-I, including stimulus control, sleep restriction, and cognitive restructuring are incorporated with circadian strategies to offer a comprehensive and individualized treatment protocol (**Table 3**).

Table 3. Integrating circadian-based interventions with CBT-I.

Step	Description	Level of Evidence	Refs
1. Assess chronotype and rhythm	Use validated tools (e.g., MEQ, MCTQ, sleep diary, actigraphy) to define baseline sleep-wake timing and rhythm stability.	Strong – multiple validation studies	(74)
2. Identify misalignment factors	Evaluate irregular light exposure, shift work, inconsistent wake or mealtimes contributing to circadian disruption.	Moderate – consistent observational links with sleep disturbance	(75)
3. Apply timing-based interventions	Implement morning bright light, limit evening light, and align activity and meals to circadian phase.	Strong – RCTs support light- and timing-based realignment	(57, 76)
4. Reinforce adherence and feedback	Use wearables or mobile tracking to support self-monitoring and sustain adherence.	Moderate-Emerging – early digital-adherence and validation trials	(48, 53)

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5. Integrate with CBT-I core	Combine stimulus control, sleep restriction, and cognitive restructuring with circadian alignment strategies (e.g., light therapy, wake-time stabilization).	Moderate – controlled and translational studies show additive benefit	(9, 77, 78)

5. Population-Specific Applications

Circadian misalignment varies across populations based on occupational demands, age, and comorbid conditions. The following sections describe applications of circadian strategies tailored to shift workers, jet lag, adolescents, older adults, and individuals with psychiatric comorbidities, highlighting population-specific considerations for assessment and intervention.

5.1. Shift Workers

Individuals who work on night shifts or rotating shifts are especially prone to circadian misalignment associated with poor sleep and impairments in alertness, performance, and well-being. A large cross-sectional study of more than 30,000 shift workers indicated that circadian misalignment not only affected sleep duration and quality, but was also associated with sleep disorders including insomnia, sleep-related breathing disorders, and sleep-related movement disorders (79). Another large study of 9,000 shift workers also demonstrated that circadian misalignment was related to obesity/overweight, poor blood pressure, and elevated triglyceride levels (80). Circadian interventions have been found to address some of these outcomes. For example, a systemic review and meta-analysis found that light therapy significantly improved total sleep time and sleep efficiency in shift workers. , where medium illuminance (900–6000 lux) with longer treatment duration (> 1 h) at night was more effective in extending total sleep time, and higher-illuminance with greater dose (lux*h) was more effective for improving sleep efficiency (81). However, the meta-analysis noted that most evidence is from short-term laboratory or field studies with small samples and substantial heterogeneity, and emphasized that optimal light therapy protocols (timing, intensity, duration) for shift workers remain incompletely defined, with most studies showing only modest effect sizes. Individual variation in chronotype and shift schedule complexity may require personalized approaches. Customized light plans (timed bright and dark light), scheduled meals and structured exercise could also help improve circadian alignment and reduce overall health and sleep effects (82).

5.2. Travelers with Jet Lag

Travelers crossing time-zones experience acute circadian misalignment, or jet lag, which is associated with insomnia, daytime sleepiness, reduced concentration, gastrointestinal issues, and mood disturbances (83). Severity of jet lag symptoms depends on an individual's chronotype, the number of time zones traveled, and the direction of time zone changes, with phase advance (eastbound travel) generally harder to accommodate than phase delay (westbound travel) (84). A systematic review of non-pharmacological interventions for jet lag found support for timed light/dark exposure, scheduled meals, and structured physical activity. However, evidence of benefit was limited and findings were mixed across studies (85). Short-term, exogenous melatonin and melatonin agonists can be used to support phase shifting, particularly for eastbound travel, but evidence suggests the need for additional behavioral strategies, such as adequate exercise, hydration, and appropriate timing of exposure to bright light (86). Pre-travel preparation, such as gradually shifting sleep-wake times prior to travel, and limiting caffeine intake earlier in the day and alcohol intake later in the day (due to their adverse effects on sleep quality) may reduce jet lag severity (86). Overall, evidence for jet lag interventions remains constrained by small sample sizes, heterogeneous protocols, and short follow-up periods. More rigorous, standardized trials are needed to guide clinical recommendations in real-world travel scenarios.

5.3. Adolescents and Delayed Sleep Phase Disorder

Adolescents have a unique circadian risk profile related to both social and biological factors. Changes in melatonin secretion during puberty naturally delay sleep timing, contributing to longer sleep latency, and adolescents are at risk of delayed sleep phase disorder (DSPD) if they consistently go to bed late and struggle to wake in the morning (87). Combined biological and behavioral strategies are typically considered for treatment in this population. A meta-analysis of 19 RCTs (n=841) in children and adolescents with DSPD showed that 4 weeks of timed melatonin treatment consistently improved sleep latency by 22–60 minutes without serious adverse effects (88). Likewise, a systematic review in this population showed clinically significant phase advances with light therapy (29). However, long-term efficacy and safety remain understudied. Lastly, behavioral interventions such as limiting late-evening screen use, scheduling consistent mealtimes, and adhering to a structured bedtime routine may also be considered to support adherence and improve sleep outcomes among adolescents.

5.4. Older Adults

Older adults aged 60 or older often exhibit weaker circadian signals and reduced melatonin secretion, compounded by limited sunlight exposure due to reduced mobility or illness, which contributes to fragmented sleep (89). Interventions therefore focus on increasing daytime light exposure and maintaining structured daily routines to support sleep consolidation (90-92). A meta-analysis of 18 RCTs involving over 1,000 older adults with dementia found moderate benefits of light therapy, including fewer night-time awakenings, improved sleep quality, and increased circadian rhythm amplitude (92). Accordingly, strategies that maximize daytime light exposure and incorporate regular activity and mealtimes may help stabilize circadian rhythms and reduce sleep disruption in this population. Comorbidities and polypharmacy (taking multiple medications) can further dysregulate circadian function, and therefore are also typically considered when tailoring interventions (93). However, most trials enrolled dementia patients in institutional settings; generalizability to community-dwelling older adults and those with primary insomnia remains uncertain.

5.5. Psychiatric Comorbidities

Circadian misalignment is also commonly associated with mood and anxiety disorders. For example, disrupted sleep-wake patterns can worsen depressive symptoms and reduce treatment responsiveness in major depression (94, 95). In bipolar disorder, sleep disruption is both related to illness severity and also contributes to mood instability and relapse (96). Clinical management of circadian misalignment in individuals with psychiatric conditions includes targeted interventions like interpersonal and social rhythm therapy (IPSRT), which stabilizes their sleep/wake schedules and daily routines (sleep, activity, meals) (97). In major depressive disorder, chronotherapies including morning bright light, and pharmacotherapies with antidepressants both improve symptoms in part by normalizing circadian phase (94). In bipolar disorder, bright light therapy has been found to decrease both the number and severity of depressive episodes (94, 96). However, timing is critical for safety: while light therapy generally carries low risk of triggering mania or hypomania, risk increases in rapid-cycling bipolar disorder. Current guidelines recommend starting with midday light therapy (12-2pm) rather than morning light to minimize this risk, with morning light used for individuals who do not respond to midday treatment and can be monitored (98, 99). Evening blue-light blocking may reduce manic symptoms, though evidence remains preliminary (94). Further studies are needed to refine treatment timing, personalization, and long-term outcomes of chronotherapies across psychiatric populations.

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6. Conclusion

This narrative review synthesized current evidence on circadian-based strategies for behavioral sleep clinicians, emphasizing practical integration with CBT-I. Recent high-quality evidence demonstrates that combined CBT-I with circadian-based strategies produces superior outcomes to either approach alone, supporting multimodal treatment frameworks. Advances in wearable technology and digital therapeutics enable monitoring of individual circadian patterns and personalized recommendations in real time, potentially improving adherence and outcomes. However, significant gaps remain in standardized protocols, optimal timing parameters, and long-term effectiveness, in particular across diverse populations. Future research should prioritize implementation science, including clinician training models, patient adherence strategies, and cost-effectiveness analysis to facilitate broader clinical adoption of circadian interventions. For clinicians, incorporating circadian considerations offers a practical way to individualize therapy, extend benefits beyond symptom relief, and promote sustained improvements in sleep and overall well-being.

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