Review / *Derleme*

DOI: 10.4274/jtsm.galenos.2025.93823

J Turk Sleep Med

The Hidden Epidemic-How Modern Society's Clock is Making Us Sick: A Review of Social Jetlag and Its Health Consequences

Gizli Salgın: Modern Toplumda Sosyal Jetlag ve Sağlık Üzerindeki Etkilerinin Derlemesi

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Abstract

Social jetlag (SJL), a pervasive public health issue in modern society, is the chronic misalignment between an individual's internal biological clock and the social demands of their daily schedule. Unlike temporary jetlag from travel, SJL represents a continuous weekly cycle of circadian disruption. It is primarily driven by fixed work and school schedules, evening exposure to artificial light, and increased use of digital devices. This review focuses on the causes and health consequences of this chronic condition, which is increasingly recognized as a significant public health concern and has been estimated to affect around 70% of individuals in industrialized nations. The consequences of SJL extend far beyond sleepiness, contributing to an increased risk of obesity, metabolic syndrome, cardiovascular disease, and a weakened immune system. It also has significant negative impacts on mental health, correlating with higher rates of depression and anxiety, as well as cognitive deficits and poor academic performance, particularly among adolescents. SJL also imposes a substantial economic burden on society through healthcare costs and lost productivity. Addressing SJL requires a multifaceted approach, including individual behavioral changes, such as consistent sleep schedules and reduced evening light exposure, alongside broader societal and policy interventions, such as flexible work hours and later school start times. Raising public awareness of SJL is crucial to transforming it from a silent epidemic into a recognized public health priority.

Keywords: Social jetlag, circadian rhythm, public health, chronotype, sleep-wake cycle

Öz

Sosyal jetlag (SJL), modern toplumda yaygın görülen bir halk sağlığı sorunu olup, bireyin iç biyolojik saati ile günlük yaşamın sosyal gereklilikleri arasındaki kronik uyumsuzluğu ifade eder. Seyahat kaynaklı geçici jetlagden farklı olarak SJL, sabit iş ve okul saatleri, akşamları yapay ışığa maruz kalma ve dijital cihaz kullanımının etkisiyle ortaya çıkan, haftalık döngüler halinde devam eden bir sirkadiyen bozulmadır. Bu derleme, sanayileşmiş ülkelerde bireylerin %70'ine kadarını etkileyen bu kronik durumun nedenlerini ve yaygın sağlık sonuçlarını incelemektedir. SJL'in sonuçları yalnızca uykululukla sınırlı kalmamakta; obezite, metabolik sendrom, kardiyovasküler hastalıklar ve zayıflamış bağışıklık sistemi riskinde artışa da yol açmaktadır. Ayrıca SJL'in ruh sağlığı üzerinde de ciddi olumsuz etkileri bulunmakta; depresyon ve anksiyete oranlarının yükselmesi, bilişsel yetersizlikler ve özellikle ergenlerde akademik başarı düşüklüğü ile ilişkilendirilmektedir. Bunun yanı sıra SJL, sağlık harcamaları ve üretkenlik kaybı nedeniyle toplum üzerinde önemli bir ekonomik yük oluşturmaktadır. SJL ile mücadele bireysel davranış değişikliklerini (düzenli uyku saatleri, akşam ışığa maruziyetin azaltılması) kapsayan, bununla birlikte esnek çalışma saatleri ve okulların geç başlaması gibi daha geniş kapsamlı toplumsal ve politik düzenlemeleri de içeren çok boyutlu bir yaklaşım gerektirmektedir. SJL'in sessiz bir salgın olmaktan çıkarılıp tanınan bir halk sağlığı önceliğine dönüştürülmesi için toplumsal farkındalığın artırılması büyük önem taşımaktadır.

Anahtar Kelimeler: Sosyal jetlag, sirkadiyen ritim, halk sağlığı, kronotip, uyku-uyanıklık döngüsü

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Received/Geliş Tarihi: 20.08.2025 **Accepted/Kabul Tarihi:** 11.11.2025 **Epub:** 18.08.2026

Cite this article as: Peşdere S, Uzun SU. The hidden epidemic-how modern society's clock is making us sick: a review of social jetlag and its health consequences. J Turk Sleep Med. [Epub Ahead of Print]

Introduction

The human body operates according to a complex, endogenous 24-hour internal clock known as the circadian rhythm. This rhythm primarily governs wakefulness and sleep cycles by responding to changes in environmental light (1). Located in the suprachiasmatic nucleus (SCN) of the hypothalamus, this intricate biological system coordinates physiological processes and behaviors, including sleep-wake cycles, hormone secretion, metabolism, and immune function, to optimize energy expenditure and the body's internal physiology (1). The fundamental functioning of this circadian system is vital for human health and well-being, as disruptions in circadian activity are associated with various adverse physiological, psychological, and clinical outcomes (2).

As a modern phenomenon, social jetlag (SJL) describes the chronic misalignment between an individual's biological clock and the social clock imposed by societal constraints, such as work and school schedules (3). Unlike travel-induced jetlag, SJL arises from persistent discrepancies in sleep timing between work or school days and free days, driven by rigid institutional schedules conflicting with natural light-dark cycles and individual chronotypes. This discrepancy often leads individuals to deviate from their natural sleep-wake cycles during weekdays, attempting to compensate on weekends. This creates a "jetlag-like" experience without actual travel (3). This chronic incongruity stems from a continuous conflict between the body's natural rhythms and social expectations, disrupting them and leading to wide-ranging health consequences. It is typically quantified as the difference in mid-sleep timing between workdays and free days (3,4). First described by Wittmann et al. (3) in 2006, SJL arises when people use alarms to wake before their natural wake time on workdays and then "oversleep" on weekends, leading to a weekly cycle of circadian disturbance (4,5).

The concept of SJL has gained prominence in recent years due to its high prevalence and potential health impacts. Epidemiological studies indicate that up to 70% of individuals in industrialized nations experience at least one hour of SJL weekly, with approximately 20–30% exhibiting misalignment exceeding two hours—a threshold consistently linked to adverse health outcomes (5-7). This widespread prevalence underscores its significance as a growing public health concern in modern 24/7 societies, where artificial lighting and around-the-clock activities contribute to circadian disruption (8).

Given the high prevalence of SJL and its initial symptoms often being perceived as milder than those of travel-induced jetlag (9), many individuals may live with chronic circadian disruption without fully realizing it or understanding its severity. Although the term "jetlag" typically refers to a temporary condition, SJL is chronic (10). Chronic circadian disruption (such as that from night shift work or jet lag) can increase risks for metabolic, cardiovascular, immune and psychiatric diseases. This chronic, often unnoticed condition, namely SJL, is becoming a kind of "invisible epidemic" silently eroding public health, as the internal-external time conflict affects sleep, behavior, and well-being on a large scale.

This review article has delved into the underlying mechanisms, causes, health effects, measurement methods, and potential prevention strategies of SJL, highlighting its critical importance as a public health issue in contemporary society.

Defining SJL: The Mismatch of Clocks

The concept of SJL emerged from observations using the Munich ChronoType Questionnaire (MCTQ), which enabled the quantitative assessment of chronic inconsistencies in sleep timing (10). The MCTQ provides a measure of chronotype and calculates SJL as the absolute difference in mid-sleep between workdays and free days (4,10).

Historically, before the introduction of time zones in the late 19th century, the "social clock" was largely synchronized with the "sun clock" (noon being when the sun reached its zenith). Modern life, with its fixed schedules and widespread use of artificial light, has significantly weakened the influence of natural light-dark cycles (zeitgebers), leading to a greater divergence between biological and social time (10). This phenomenon was first described in 2006 when researchers noticed that individuals in sleep diaries consistently appeared to be "flying west on Friday evenings and returning on Monday mornings" without actually traveling (10).

SJL represents a chronic discrepancy between internal and external timing (10). While SJL often involves accumulated sleep debt during weekdays due to early wake-up times and late bedtimes, it fundamentally concerns the misalignment of circadian rhythms, not merely insufficient sleep duration (10). Individuals can experience SJL even without a weekday sleep deficit (8). This distinction is crucial because the health effects of SJL are attributed to this chronic circadian disruption, not solely to sleep deprivation (11). SJL is defined by differences in sleep midpoints, suggesting that individuals try to "catch up on sleep" on weekends (3). However, oversleeping on weekends, while compensating for sleep debt, increases SJL by delaying the free-day sleep midpoint (7). This indicates that the act of "catching up" perpetuates the misalignment, creating a continuous cyclical problem. As the body constantly tries to adapt, societal pressures pull it back.

Circadian Mechanisms and Chronotypes - Mechanisms of Circadian Misalignment

Biological clocks coordinate almost every aspect of human physiology with the 24-h day. The human circadian system is regulated by a central "master clock" located in the SCN of the hypothalamus (2). The SCN synchronizes the 24-hour rhythms of various physiological functions and behaviors throughout the body (2). The SCN is reset daily by "zeitgebers" or time cues from the external environment, which allows the body's internal rhythms to synchronize with the outside world (12). Circadian rhythms are synchronized to the external environment primarily by "zeitgebers" (German for "time givers"), with light being the most dominant and powerful cue (8). Natural light-dark cycles entrain the biological clock to solar time, ensuring that

the internal biological night begins near sunset and ends near sunrise (13). Reduced exposure to daylight and increased exposure to artificial light at night can delay circadian and sleep timing (13).

Humans exhibit significant individual differences in their preferred sleep and activity timing, known as chronotypes, which are largely regulated by genetic variations in clock genes and environmental influences (3). These chronotypes range from "early types" (larks) who prefer earlier sleep and wake times, to "late types" (owls) who prefer later timings, with most individuals falling into "intermediate types" between these extremes (3). Most individuals are intermediate, but chronotype follows a near-normal distribution across populations (7,14). Chronotype depends partly on genetics and age: children tend to be early types, while puberty shifts clocks later; adolescents peak in "night owl" preference around ages 16–18 (7,15). Morning types preferentially wake and sleep early, with peak alertness in the morning, whereas evening types naturally go to bed late and wake late (7,14). Evening chronotypes report feeling and performing best in the late afternoon or evening (16).

The standard organization of modern society often favors early chronotypes, forcing late chronotypes to conform to routines that conflict with their internal biological time (8). This is particularly evident in fixed school and work schedules that require early wake-up times (3). This interference creates a chronic discrepancy between an individual's preferred sleep timing and their actual sleep timing on workdays, leading to SJL (3).

The human circadian system has evolved over billions of years to synchronize with natural light-dark cycles (1). However, modern society, especially since the widespread availability of electricity, has significantly weakened natural zeitgebers and introduced artificial light at night (10). This means the "social clock" has largely decoupled from the "sun clock," forcing human biology to work against its evolutionary programming. This suggests that addressing SJL is not merely about individual discipline but requires a fundamental re-evaluation of societal structures and environmental design. Public health strategies should acknowledge this "forced evolution" and advocate for changes in the built environment and societal schedules to better align with natural human biology.

Furthermore, light is the most powerful natural zeitgeber (8). However, modern lifestyles involve widespread exposure to artificial light, particularly blue light from digital devices, which directly suppresses melatonin secretion and delays circadian timing (17). This indicates that digital devices may not only contribute to SJL but may also act as a new, artificial zeitgeber that actively misaligns our biological clocks, often overriding natural light cues.

Causes and Contributing Factors of SJL

SJL arises whenever societal schedules force a mismatch with biological timing (7,10). Because adolescents naturally shift toward a later chronotype during development, they are particularly vulnerable to SJL when required to adhere to conventional early school start times (3,5,18). The increasing demand for productivity and competitiveness in modern society contributes to routines that diverge from an individual's internal time (8). Shift work, particularly night shifts, is a major contributor, forcing individuals into unnatural light-dark patterns, leading to severe circadian disruption and high levels of SJL. Permanent night shift workers experience the highest SJL (e.g., 5:08 hours) (8). Early school start times are also a significant contributing factor. Conventional 8–9 AM school start times are often too early for adolescents and many young adults. To meet those obligations, they must wake before their internal clock signals full alertness, using an alarm to truncate sleep (3,5).

The widespread availability of artificial light, especially in the evenings, has profoundly impacted circadian rhythms (10). Living predominantly indoors shields individuals from full daylight exposure, while evening artificial light delays biological clocks (10). Excessive exposure to blue light from electronic devices (smartphones, laptops, tablets) is a critical modern factor (19). Blue light, particularly at wavelengths of 400-500 nm, suppresses melatonin secretion, which is vital for sleep regulation, and can significantly delay sleep onset, thereby disrupting circadian rhythms (17). Recent adolescent studies show that bedtime screen use correlates with a later chronotype and increased SJL (20). Studies show that even 2 hours of LED tablet exposure can reduce melatonin levels by 55% and delay its onset by 1.5 hours (17). Thus, digital lighting and 24/7 media consumption exacerbate the misalignment. In summary, chronotype–social clock conflict is at the core: evening types are forced to conform to early schedules, while society seldom adjusts to their biology (3). Any pressure to advance sleep (social clock) or delay it beyond natural timing can produce SJL.

Health Effects of SJL: A Broad Spectrum of Adverse Outcomes

SJL, as a consequence of disrupted circadian rhythms, is a complex public health issue leading to a wide range of physical, mental, and behavioral health problems. This condition is not merely limited to sleep patterns but represents a chronic state of misalignment affecting multiple bodily systems. SJL is strongly associated with poor sleep quality and increased daytime sleepiness (3). Studies show that individuals with ≥2 hours of SJL experience significantly higher daytime sleepiness (21). Studies have found that high-SJL individuals exhibit reduced heart rate variability during sleep (a sign of poorer sleep quality) and report more fatigue (7). In effect, SJL often doubles as an ongoing form of insomnia/deprivation on weekdays.

SJL is significantly associated with various cardiometabolic risk factors. High-quality studies indicate that SJL is associated with a higher body mass index (BMI), increased waist circumference, higher systolic blood pressure, and elevated glycated hemoglobin (22). Studies found that people with longer SJL had higher fasting cortisol levels and a dyslipidemic profile (higher triglycerides, total cholesterol, and glucose) than those with minimal SJL (4,23-26). At the population level, SJL has been associated with higher BMI and waist circumference.

Several epidemiological studies report that greater SJL predicts a higher prevalence of obesity and metabolic syndrome (7,15). Thus, SJL appears to contribute to the modern epidemics of overweight, metabolic syndrome and type 2 diabetes.

SJL is also positively correlated with mental health issues, particularly depressive and anxiety symptoms in young people and workers, with individuals experiencing ≥2 hours of SJL showing higher odds of clinically significant depression and anxiety (5,27-29).

Behavioral risk factors linked to SJL include higher rates of smoking (30,31), increased alcohol consumption (32), and poorer diet quality with higher intake of sugary beverages, total fat, and saturated fat (33).

In one survey, teens reporting night-time screen use had significantly more SJL, which mediated effects on mood and anxiety (20). SJL has been associated with multiple adverse health outcomes. It is linked to a weakened immune system and circadian rhythm disruptions.

Furthermore, SJL is associated with cognitive deficits, including reduced crystallized intelligence and lower academic performance from early adolescence through university (30,31), as well as a lower overall quality of life (27). In children with autism spectrum disorders, SJL correlates positively with core symptoms, particularly in 2–3-year-olds, indicating their sensitivity to routine changes (34).

While direct associations with occupational accidents are less clear, shift work—a major cause of SJL—is linked to increased accident risk, reduced psychomotor vigilance, and impaired workplace alertness and performance (7,35,36). Collectively, these findings underscore that SJL is a significant public health concern that affects multiple domains of well-being. Assessment and management of SJL should be integrated into clinical practice, especially for patients predisposed to metabolic, sleep, or mental health disorders, and public health screenings could incorporate SJL evaluation to identify at-risk populations where disease progression might be prevented.

Economic and Societal Burden of SJL

The economic burden of SJL is substantial and quantifiable. A spatial regression discontinuity study conducted along US time zone borders takes advantage of a unique natural experiment. Counties on the western edge of a time zone experience later sunsets but follow the same clock times and social schedules as counties on the eastern edge. Utilizing data from the American time use survey and the behavioral risk factor surveillance system, researchers found that an additional hour of evening natural light reduces average sleep duration by 19 minutes and significantly increases the probability of insufficient sleep (defined as <6 hours) (37). The misalignment leads to a 0.3 standard deviation decline in a composite health index, reflecting higher population-level rates of obesity, diabetes, cardiovascular disease, and breast cancer on the late sunset side of the border (37). Notably, no significant residential sorting—measured through home values, rents, or commuting patterns—was observed, suggesting that individuals do not relocate to mitigate circadian disruption, likely due to structural constraints or behavioral trade-offs between evening leisure and sleep (37). This natural experiment provides robust causal evidence on the health effects of socially imposed timing. It shows that circadian misalignment—independent of individual behavior—contributes to population-level health disparities. The economic burden of SJL is estimated to result in at least $2 billion in annual healthcare expenditures and the loss of 4.4 million workdays due to reduced productivity and increased illness (37). At the individual level, SJL exceeding two hours is associated with an 18% reduction in work ability index scores, a validated metric of work capacity and functional ability (36).

Measurement of SJL

Accurate assessment of SJL is a fundamental step for research, clinical awareness, individual interventions, and public health strategies. The MCTQ is the most widely used self-report tool for assessing chronotype and quantitatively determining SJL (38). It calculates SJL as the absolute difference between the midpoint of sleep on free days and the midpoint of sleep on work/school days. A "sleep-corrected" version (SJLsc) has been proposed to account for accumulated sleep debt, which might otherwise overestimate SJL (39). The MCTQ is a quick, cost-effective, and non-invasive tool that has been validated across diverse populations, making it well-suited for large-scale epidemiological studies of chronotype and SJL. In research, SJL is often categorized (e.g., <1 h, 1–2 h, ≥2 h) to examine dose–response relationships with health outcomes. The Morningness-Eveningness Questionnaire is another tool used to assess diurnal preferences and categorize individuals into morningness-eveningness types, showing good correspondence with MCTQ chronotype (40). Other approaches include actigraphy and circadian phase markers. Wrist actigraphy (wrist motion tracking) is used to objectively measure sleep-wake intervals and derive sleep parameters, including sleep midpoint, which can then be used to calculate SJL. It provides a more objective assessment compared to self-reports. Objective physiological markers of circadian phase include Dim light melatonin onset (DLMO) and core body temperature acrophase (7,41). DLMO is considered the gold standard for assessing the phase of entrainment (41).

SJL research often suffers from varying methodologies and definitions, making comparisons across studies challenging. Self-reported sleep data, while practical, can be prone to bias, especially in individuals with emotional problems. Objective measures like DLMO are expensive and invasive, limiting their use in large-scale epidemiological studies. The initial SJL calculation can be confounded by sleep debt, leading to overestimation; sleep-corrected versions aim to address this (39). This creates a "measurement dilemma" for public health in accurately assessing SJL prevalence and impact across large populations without prohibitive costs or methodological compromises. Surveys like the MCTQ remain the standard for epidemiological assessment of SJL.

Prevention and Mitigation Strategies: A Multifaceted Approach

Given the high prevalence and wide-ranging health effects of SJL a multifaceted approach is necessary to address this public

health issue. These strategies extend from individual behavioral changes to technological solutions and broad societal policies.

Individual Strategies

The cornerstone is promoting regular sleep–wake schedules even on free days. Maintaining consistent sleep-wake patterns, even on weekends, is critical to minimize SJL. Reducing evening blue light exposure can advance melatonin secretion and sleep onset, helping late chronotypes better cope with early social schedules (42). Conversely, increasing morning light exposure can also help advance circadian timing (42). These behavioral changes are key for individuals to take control of their circadian health. Educational programs, such as teacher-led sleep education and awareness interventions, show promise in improving total sleep time and reducing SJL in adolescents (43). Such programs can advance sleep onset and significantly decrease SJL, especially in those with severe SJL at baseline (43). Given the impact of evening blue light from digital devices on melatonin suppression and circadian disruption (17), technological interventions, such as blue light-blocking glasses or screen filters (e.g., orange or amber-tinted lenses) can reduce short-wavelength light exposure before bedtime (42). While findings are mixed, some studies suggest these filters can improve sleep efficiency and total sleep time, particularly in individuals prone to sleep disturbances (44). Overall screen time management, especially at night, is also critical (19). Many sleep-tracking apps help individuals monitor their sleep timing and consistency, potentially flagging excessive weekend oversleep. These digital tools could be adapted to target SJL by promoting consistent sleep schedules and adjusting light exposure.

Societal and Policy Interventions

Aligning societal schedules with human biology is crucial for reducing SJL. Flexible work hours and later school start times for adolescents can help minimize the chronic discrepancy between work or school demands and biological time, particularly for late chronotypes (3,10). The abolition of daylight saving time has also been proposed to reduce the circadian misalignment imposed by it (11). Urban planning that maximizes daytime light exposure while minimizing night-time artificial light can support circadian rhythms and further reduce SJL (12).

Public health initiatives play a key role in raising awareness about the significance of SJL (8,19). While individual strategies—such as managing evening light exposure and maintaining consistent sleep routines—can provide meaningful benefits, they are insufficient on their own. Effectively addressing SJL requires systemic changes in work, school, and societal scheduling practices, particularly for vulnerable groups such as adolescents and shift workers. A comprehensive, "whole-of-society" approach is therefore needed, in which individual behaviors are supported by enabling environments and reinforced through evidence-based policy measures.

Conclusion

SJL, characterized by the chronic misalignment between our biological clocks and societal demands, is a prevalent and often underestimated public health issue in modern industrialized societies. Its high prevalence in various age groups, particularly among adolescents and young adults, underscores its profound societal impact.

The roots of SJL are deeply embedded in modern lifestyles, including fixed work/school schedules, shift work, and the pervasive presence of artificial light, especially blue light from digital devices, which disrupts natural circadian entrainment. The consequences extend beyond mere sleep disturbance, encompassing a broad spectrum of adverse health outcomes. Despite increasing awareness, the precise causal pathways and long-term consequences of SJL remain poorly understood. Addressing these gaps will require large-scale, population-based longitudinal studies. Interdisciplinary research, integrating chronobiology, public health, medicine, and the social sciences, is essential to fully unravel the complex interplay of factors contributing to SJL and its health effects. Given these findings, an equity-focused perspective is essential. Data suggest that the prevalence and health consequences of SJL may differ across socioeconomic, ethnic, and gender groups, potentially reinforcing existing health disparities. Public health research should explicitly investigate the differential prevalence and impact of SJL in diverse demographic groups. Interventions should be tailored to address specific vulnerabilities and ensure equitable access to circadian health resources, making SJL a component of broader health equity initiatives. Public health organizations must lead awareness campaigns to educate communities about the profound importance of circadian health. Prioritizing circadian alignment is not just about improving sleep; it is about building a healthier, more resilient society.

Footnotes

Authorship Contributions

Concept: S.U.U., Design: S.P., S.U.U., Data Collection or Processing: S.P., Analysis or Interpretation: S.P., S.U.U., Literature Search: S.P., S.U.U., Writing: S.P., S.U.U.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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