



Environmental Determinants of Insufficient Sleep and Sleep Disorders: Implications for Population Health

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Abstract

Purpose of Review Sleep is important for overall health and well-being. Insufficient sleep and sleep disorders are highly prevalent among adults and children and therefore a public health burden, particularly because poor sleep is associated with adverse health outcomes. Emerging evidence has demonstrated that environmental factors at the household- and neighborhood-level can alter healthy sleep. This paper will (1) review recent literature on the environmental determinants of sleep among adults as well as children and adolescents and (2) discuss the opportunities and challenges for advancing research on the environment and sleep. **Recent Findings** Epidemiologic research has shown that social features of environments, family, social cohesion, safety, noise, and neighborhood disorder can shape and/or impact sleep patterns and physical features such as light, noise, traffic, pollution, and walkability can also influence sleep and is related to sleep disorders among adults and children. Prior research has mainly measured one aspect of the environment, relied on self-reported sleep, which does not correlate well with objective measures, and investigated cross-sectional associations. Although most studies are conducted among non-Hispanic white populations, there is growing evidence that indicates that minority populations are particularly vulnerable to the effects of the environment on insufficient sleep and sleep disorders.

Summary There is clear evidence that environmental factors are associated with insufficient sleep and sleep disorders. However, more research is warranted to evaluate how and which environmental factors contribute to sleep health. Interventions that target changes in the environment to promote healthy sleep should be developed, tested, and evaluated as a possible pathway for ameliorating sleep health disparities and subsequently health disparities.

Keywords Physical environment · Neighborhood factors · Insufficient sleep · Sleep disorders · Health disparities

Introduction

Sleep, a modifiable health behavior, is increasingly recognized as integral for optimal health and well-being. Although the American Academy of Sleep Medicine recommends that adults sleep 7 to 9 h per night [1], 34.8% of Americans report less than 7 h of sleep [2, 3]. Sleep disorders such as sleep apnea and insomnia are also highly prevalent, mostly undiagnosed and a

pressing public health burden [4–10]. Insufficient sleep (defined here < 7 h adults) and sleep disorders impact daily functioning, mood, cognition, and cardiovascular outcomes such as obesity, diabetes, high blood pressure, stroke, and heart attacks [11–15]. Racial/ethnic minorities as well as individuals of lower socioeconomic status have a high prevalence of insufficient sleep and unrecognized sleep disorders [16, 17]. This high prevalence of poor sleep health, particularly among vulnerable

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populations, is influenced by many factors including environmental (e.g., sleeping conditions, housing, neighborhoods) which are also associated with poor health outcomes. To reduce the subsequent health impact of poor sleep, it is important to identify and potentially target the most pertinent determinants of sleep health, which include various environmental factors. In this article, we will review the adult and pediatric literature on environmental factors, including the household as well as social and physical environmental context in relation to insufficient sleep and sleep disorders. We will also discuss the public health significance and opportunities and challenges for future research on the environmental determinants of sleep health.

Search Strategy

To review the state of the literature on environmental determinants of insufficient sleep and sleep disorders, we utilized several search techniques to identify manuscripts. We identified articles from English language publications in PubMed. Medical Subject Headings (MeSH) of the National Library of Medicine and keywords such as environmental determinants of sleep, neighborhoods, social environment, family context, physical environment, built environment, traffic, artificial light, circadian rhythm disorders, sleep apnea, and insomnia were used. Once relevant articles were identified, we also reviewed the reference lists to identify other relevant articles. A list of the most recent (5 years) or seminal articles on environmental determinants of insufficient sleep and sleep disorders is highlighted in the sections below.

Adult Sleep

In this section, we will discuss the environmental determinants of insufficient sleep and explore how the social and physical neighborhood environment may contribute to the most common sleep disorders: circadian rhythm disorders, sleep apnea, and insomnia among adults. First, we provide an overview of the current research on various features of the environment that have been studied in relation to insufficient sleep. We then discuss the most common sleep disorders individually, with reviewing the prevalence, data on the environmental effects, and the potential mechanisms.

Insufficient Sleep

Although understudied, growing research has demonstrated that environmental factors can alter healthy sleep. More traditionally, researchers have examined specific features of the environment such as inopportune light exposure, vehicular traffic noise (including air, road, and rail), temperature, and humidity which can limit sleep opportunity [18–20, 21•, 22•, 23–25]. More recently,

sleep researchers have adopted a social ecologic perspective and have explored the social neighborhood environment as well as additional features of the physical neighborhood environment in relation to sleep. Using epidemiologic data, researchers have shown the social neighborhood environment (e.g., social cohesion, safety, violence, disorder) and the physical neighborhood environment (e.g., walkability, green space, density) are associated with sleep duration, daytime sleepiness, sleep difficulties, and sleep quality [26•, 27–37, 38•]. These prior studies have included both self-reported and objective measures of sleep, most commonly sleep duration. In general, studies have reported that adverse neighborhood environments are associated with sleeping between 7 and 11 min less on average, after adjustment for age and sex [28•, 34•, 38•, 39•]. Observational studies have demonstrated that selecting a room with at least one window that faces green space or water as well as exposure to natural amenities (green space) attenuates the likelihood of insufficient sleep [32, 40]. Grigsby-Toussaint and colleagues found that participants who reported 21–29 days vs. 1–6 days of insufficient sleep had a lower odds of exposure to natural amenities [Odds ratio: 0.84, 95% confidence interval (CI) = 0.75, 0.95] [32, 40]. Although most of the prior studies examined specific aspects of the social or physical environment, there is evidence that a composite measure of the social neighborhood environment (e.g., combination of safety and social cohesion) is associated with both self-reported and objectively measured sleep [28•, 34•]. For example, a standard deviation increase in the social neighborhood environment score was associated with sleeping 9 min (CI: 5.4, 13.5) more on average after adjustment for age and sex [28•, 34•]. Inclusion of a composite measure provides an estimate of the cumulative impact of the environment on sleep. Data from the Multi-Ethnic Study of Atherosclerosis (MESA) showed that the built neighborhood environment (higher street smart walk score, more social engagement destinations, street intersections, and population density) was related to a 17–23% higher odds of short sleep duration (≤ 6 h) [39•]. This finding demonstrates the complex relation of the built environment and sleep. For example, more destinations and higher density may promote walking which is beneficial for health, but these same features can also promote noise, traffic, pollution, and inopportune light exposures which can reduce sleep opportunity.

Another frequently studied aspect of the neighborhood environment in relation to sleep is neighborhood disadvantage. Although several studies have examined neighborhood disadvantage and insufficient sleep, the findings are largely inconsistent [26•, 27, 29–31, 34•, 35, 37•, 41•, 42]. The lack of findings may be due to the different measures of neighborhood disadvantage and subjective sleep metrics or that disadvantage is associated with other causative environmental factors contributing to sleep health. For example, higher exposure to air pollution is more common in disadvantaged neighborhoods [43]. As discussed later in the article, the association between neighborhood disadvantage and insufficient sleep is observed among

pediatric populations. However, in total, it is evident that the neighborhood context impacts sleep patterns, both in timing, duration, and quality. It is also hypothesized that insufficient sleep may be on the pathway between neighborhood disadvantage and poor health outcomes [29, 44•, 45]. Prior research has shown that the neighborhood environment is associated with cardiovascular outcomes; therefore, it is plausible that sleep may mediate the association between the neighborhood and cardiovascular outcomes [44•, 46, 47].

There are several potential pathways that may link the environment to insufficient sleep. The physical and social environment may act together to delay sleep behaviors or arouse early (e.g., street noise, awake neighbors, noisy construction). The environment may also have an indirect association through stress, which is associated with insufficient sleep [48, 49]. For example, residing in an adverse neighborhood environment, fear of crime and violence, may increase anxiety or affect mood (e.g., depression), which may lead to dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, lead to hyperarousal/hypervigilance and less time available for sleep [50].

Insomnia

Sleep disorders are extremely common in adults with insomnia being one of the most prevalent and costly. An estimated 10% suffer from chronic insomnia with 35% experiencing insomnia symptoms annually. Insomnia, which is measured subjectively, is characterized as difficulty initiating and/or maintaining sleep, awakening too early, with a resulting daytime impairment [51]. Insomnia leads to loss of productivity, higher risk of cardiovascular disease, and greater health care utilization [44•]. The risk of insomnia is higher among women, elderly, and those with depression, anxiety, and chronic health conditions [52]. Insomnia symptoms are also more prevalent in those with greater financial and social stressors [37•, 53].

Contextual features of the neighborhood likely contribute to insomnia. Living in disadvantaged neighborhoods has been associated with insomnia symptoms. Recent investigations have explored how the social, political, and physical context surrounding the sleeping environment may contribute to sleep disorders [54]. The same environmental features that lead to insufficient sleep as noted above (e.g., fear for safety, noise from crowding), likely also contribute to insomnia symptoms by impairing sleep onset and promoting hyperarousal. Noisy neighborhoods were associated with a 4% greater prevalence of insomnia symptoms in a national epidemiological study of Hispanics and Latinos [37•]. Poverty, neighborhood disorder, and violence are associated with poor sleep quality and insomnia symptoms [34•, 37•, 55]. Clustering of insufficient sleep regionally, such as is seen in American Appalachia, may be related to prevalent insomnia symptoms due to regional poor health, reduced access to health care and economic disparity [56]. Objective measures of insomnia, such as a greater wake

after sleep onset, have also been associated with neighborhood disadvantage [57].

Noise pollution can also foster insomnia in susceptible urbanites. A study in Oslo found 5% greater odds of difficulty falling asleep and too early awakenings per 5-dB increase in traffic noise [62]. Loud noises from trucks, trains, planes, sirens and highways, and sounds related to a high density of people also disrupts sleep and may lead to insomnia symptoms [19, 20, 58•, 59].

Circadian Rhythm Disorders: Phase Delay

The physical environment may foster circadian rhythm disorders through several mechanisms. Excess artificial light from streets, residences, and businesses in the urban setting may disrupt circadian rhythms by depressing melatonin secretion which impacts the initiation of sleep. Artificial light can cause circadian phase delay and prolong sleep latency [60]. In a study of the US population, those with greater outdoor nighttime lights exposure had a 28% greater odds of a circadian phase delay. Those living in brighter areas at night, typically in dense cities, had a later bedtime [61•]. Light exposure at night can decrease melatonin secretion and lead to increased objective sleep disturbance and subjective insomnia in the elderly [62]. Greater use of screen-based media (e.g., smart phones, TVs, tablets) with the associated artificial light in the bedroom is associated with insomnia symptoms, delayed sleep, and wake time [63]. Individuals in urban environments may also be deprived of natural daylight and have excessive exposure to computer screen light in their work place; this, plus shift work, may also lead to circadian misalignment and insomnia [64].

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) is very common in the general adult population, with an increasing prevalence as obesity becomes more widespread. An estimated 5–26% of US adults have sleep apnea, with many undiagnosed [65]. OSA is a disorder of repeated upper airway narrowing or collapse, leading to disrupted sleep and oxygen desaturation; severity is measured by the frequency of apneas and hypopneas (reduced air flow) per hour of sleep or apnea hypopnea index (AHI). It is associated with cardiovascular disease, arrhythmias, stroke, diabetes, daytime sleepiness, cognitive impairment, and motor vehicle accidents [13, 66]. Obesity, cranio-facial anatomical features, and airway tone all contribute to the pathology, but environmental factors are associated with the disease as well.

Environmental features, specifically neighborhood-level, may promote obesity and metabolic disease [47, 67]. Sleep apnea is highly correlated with obesity, with greater prevalence and severity among the morbidly obese [65]. Features of the built and social environment can influence the risk of obesity and physical activity levels, including walkability,

access to healthy food stores, recreation, safety, social cohesion, street connectivity, and green spaces [68, 69, 70, 71, 72]. Living in neighborhoods with a poor walking environment is associated with a greater severity of OSA (AHI increase by an average three more events per hour in adjusted analysis among those living in the lowest walking environment), markedly in persons with obesity [27]. Neighborhood crowding has also been associated with sleep apnea, mediated by body mass index (BMI) [73].

Environmental features such as traffic and ambient air pollution have also been associated with OSA. Individuals exposed to higher levels of ozone and PM₁₀ were found to have greater desaturation and severity of sleep apnea, particularly in the summer in several studies [74, 75, 76]. In a recent study in Taiwan, a higher exposure to PM_{2.5} and NO₂ was associated with a 4–5% greater AHI [75]. Living near roads can lead to greater sleep disruption from traffic noise and associated pollution; proximity to traffic has been associated with greater sleep apnea symptoms such as snoring and daytime sleepiness [77, 78]. An adverse physical environment may result in exposure to inflammatory irritants that increase OSA propensity [79, 80].

Pediatric Sleep

In this section, we provide an overview how environmental context may affect sleep among youth. We first review the prevalence of insufficient sleep and sleep disorders among youth populations, then highlight current research on studies of the role of family and household context on pediatric sleep, and conclude with findings about the role of neighborhood disadvantage and pediatric sleep health.

Insufficient Sleep and Sleep Disorders

Throughout childhood and adolescence, many youth suffer from a range of sleep problems and sleep disorders. Some of these, such as OSA and restless leg syndrome, are medically based disorders, while others are behaviorally based disorders (such as, behavioral insomnia of childhood) [81]. In the early years, birth through age 3 estimates indicate that between 20% and 30% of children suffer from sleep problems, primarily behavioral [82–84]. Through the school-aged years, children's sleep disturbances tend to wane and OSA occurs in up to 6% of youth [85–87]. Studies show that heavier children, male children, and African American children are each independent risk factors for having sleep-disordered breathing [87]. Sleep insufficiency is highly prevalent among youth, especially among adolescents. An estimated 70–90% [88, 89] of teenagers are not getting their recommended hours of sleep [90].

Family and Household Context

Starting early in life, family and household contextual factors are associated with youth sleep patterns. The home environment encompasses family behaviors which shape sleep patterns. During infancy, studies link maternal depression and anxiety to increased number of infant sleep problems, including night time awakening and more crying at bedtime [91–94]. Marital stability at age 9 months is longitudinally predictive of child's bedtime resistance 9 months later [95] and difficulty falling asleep and staying asleep at age 4.5 years [96].

The Auburn University Sleep Study, which follows 250 9- to 11-year-old children in nonurban areas of the southeast, provides a rich source of information on family and sleep. The study has found that children from less-advantaged homes sleep less by about 35 min per night [97, 98] and have more actigraphy-assessed movement at night, compared to children from more advantaged homes [99]. Further, behaviors witnessed in the household such as parental depression are associated with less time in bed and more nighttime activity among children [100]. And finally, family conflict is associated with children's poorer sleep quality [99, 101, 102]. Other studies of school-aged children show that parental socioeconomic status, such as parental education, parental social capital, and financial security, is associated with better sleep among children [103–105].

During the teenage years, family and household environment matters for sleep in a variety of ways, including parental behaviors, family structure, and again, family socioeconomic status. For example, teenagers show a concordance in sleep, bed, and wake times with their parents' behaviors [106]. Teens from single-parent households have lower sleep efficiency during the week and shorter sleep duration on the weekend than those from two-parent households [107]. In addition, seventh graders in families with low-socioeconomic status go to bed later and have shorter sleep durations than those from families with higher socioeconomic status [108]. Some of the other modifiable factors associated with insufficient sleep and sleep difficulties among older youth include chaotic household [109], unenforced sleep routines [89, 109], screen-based media activity [110, 111], and early school start times [112–114]. Efforts to start high school start times later than 8:30 am have shown encouraging results, increasing sleep duration by around 20 min according to one meta-analysis, and improving health and other adolescent outcomes [115, 116].

Neighborhood Disadvantage

Research on neighborhood context and sleep as described above has primarily focused on adults [29–31, 34, 35, 42], but several studies have investigated neighborhood context

and sleep among children [117–119] and adolescents [119–122]. One analysis shows that infants living in more urban areas sleep less per day than infants living in the least urban areas [117]. A cross-sectional study of school-aged children demonstrates that neighborhood disadvantage is associated with increased risk of OSA, even after adjustment for race and body mass index [118]. Data from the National Survey of Children's Health shows that children (ages 6–17) who lived in neighborhoods with fewer health promoting amenities or greater social disadvantage had increased odds (around 40%) of serious sleep problems [119]. And other research has found that teens with exposure to community violence and hopelessness had increased risk of disturbed sleep and daytime sleepiness [120, 121, 122]. Consistent with the work on the benefits of health-promoting amenities, one study found that neighborhoods with increased opportunities for physical activity, such as access to recreational facilities, were associated with teenagers getting more total sleep time and a later morning wake time. Specifically, for each unit increase in access to recreational facilities (on a scale of 0–5) the teenager slept 9 min more per night [123].

Public Health Significance

Exposure to adverse environmental conditions tends to be patterned by race and socioeconomic status [124], which perpetuates health disparities, particularly sleep health disparities. Racial minority populations have shorter sleep duration, poorer sleep quality, and more severe sleep apnea according to well-validated subjective and objective measurements [16]. Studies among racial minority populations have shown that the neighborhood environment is an important determinant of insufficient sleep for minorities [26, 28, 38]. For example, data from the Jackson Heart Study demonstrated that neighborhood violence and disorder were associated with a shorter sleep duration and a poor sleep quality [27]. Similarly, among the diverse MESA cohort, researchers found an association between the neighborhood social environment and sleep outcomes among African Americans, but not among other racial/ethnic groups [28]. If sleep health is a fundamental contributor to cardiovascular health disparities, then ameliorating sleep health disparities can potentially improve overall population health [125].

Despite emerging research interest in the environmental determinants of sleep, more research is warranted to evaluate how and which environmental factors contribute to sleep health. With the growing prevalence of insufficient sleep and sleep disorders, there is a clear need to understand the upstream determinants that shape sleep health. Future studies should include more rigorous measures of the environment, such as objective real-time monitoring of air quality, traffic, and noise as well as geographic information systems-based measures that can provide more accurate assessments of the

built environment. Also, more longitudinal studies of the environment and sleep are needed, in order to better define the temporal and potentially causal relationship. Another challenge to population sleep health research is the reliance on subjective measures of sleep which are more convenient and less time consuming to collect, but do not correlate well with objective sleep measures [126]. Utilizing commercially available consumer devices may be a way to gather objective data on the timing and duration of sleep at a lower cost than traditional actigraphy for longer periods of data collection [127]. Studies among adult populations tend to lack data regarding household features, which limits our ability to assess the impact of the in-home environment on sleep. There may be within-neighborhood variability to environmental exposures, and housing characteristics (e.g., structure, size, building type) may modify the effects of environmental exposures or act as a direct stressor on sleep [128, 129]. Thus, there is a need to investigate household-level characteristics and in-home activities in relation to adult insufficient sleep and sleep disorders. Epidemiologic research can be enhanced by more continuous objectively measured sleep through actigraphy or other wearable devices, allowing for analyses to test whether sleep is partially explaining associations between environmental context and physical health outcomes.

Conclusions

Given the substantial evidence that indicates sleep is associated with several poor health outcomes (e.g., obesity, diabetes, hypertension, stroke, mortality, etc.), enhancing sleep research may reduce public health burden. Interventions to improve sleep should target the home sleeping environment (e.g., shades, temperature control, smart home lighting), physical environment (e.g., traffic, light, and noise reduction), urban planning to improve the social environment, as well as policies to improve neighborhood safety and air pollution. Improving the urban environment has the potential to improve sleep health as well as population health. Interventions that target changes in the social and physical environment to promote healthy sleep should be developed, tested, and evaluated as a possible pathway for ameliorating both sleep health disparities and overall health disparities.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

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