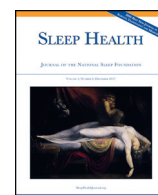




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Exposure to neighborhood green space and sleep: evidence from the Survey of the Health of Wisconsin

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ABSTRACT

Introduction: Adequate sleep duration and quality are protective against many adverse health outcomes. Many individual-level predictors of poor sleep have been examined, but few studies have examined neighborhood-level influences. Despite known associations between neighborhood green space and sleep influencing factors (eg, physical activity, mental health), few studies have examined green space and sleep's relationship. Furthermore, little work has examined the relationship between the magnitude and type of neighborhood sounds and sleep.

Study methods: We analyzed data from the Survey of the Health of Wisconsin database (n = 2712) for 2008-2013, a representative sample of Wisconsin residents ages 21-74. Outcomes included weekday and weekend sleep duration and self-rated sleep quality. Primary predictors were the proportion tree canopy (National Land Cover Database) and mean decibel levels of outdoor sound (US National Park Service) at the census block group level. Survey regression analysis was used to examine statistical associations, controlling for individual and neighborhood-level covariates.

Results: Models suggest a significant relationship ($P < .05$) between weekday sleep duration and green space, and between weekend/day sleep duration and human-made and total neighborhood sound. Increased percent tree canopy in a census block group was associated with lower odds of short weekday sleep (<6 hours) (OR 0.76 [0.58-0.98]). Increased human-made and total mean decibel levels were associated with increased instances of short weekend and weekday sleep (OR 1.05 [1.01-1.08] and 1.03 [1.01-1.06] respectively).

Conclusions: Neighborhood tree canopy and sound levels may influence sleep duration and are potential targets for neighborhood-level interventions to improve sleep.

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Introduction

Few studies have considered neighborhood-level influences on sleep beyond neighborhood socioeconomic status, despite observed spatial patterning of insufficient sleep, including across counties of the contiguous United States.¹ Most studies of neighborhood factors and sleep outcomes that have reached beyond socioeconomic factors have focused on physical and social disorder. Studies have shown that people who feel safer from crime and violence in their neighborhoods have better sleep outcomes.^{2,3} Further examinations have shown associations between low perceived neighborhood quality and low self-rated health, both of which have associations with adverse sleep outcomes, and neighborhood social environment

inadequacy has been correlated with short sleep duration.^{2,4,5} Studies have also shown that small improvements to inadequate living facilities can improve the sleep quality among residents.⁶ Neighborhood population composition has also been explored, with the potential pathway linking neighborhood composition to sleep has been suggested to be psychological distress diminishing protective psychological resources.⁷ These findings have suggested that low quality sleep may be part of the link between poor neighborhood quality and poor health.⁵ Altogether, literature to date that focuses on neighborhood influences on sleep has considered only a small number of neighborhood characteristics, with a significant emphasis on neighborhood perceptions, socioeconomic status, housing infrastructure quality, and crime. Less emphasis has been placed on natural environmental features of neighborhoods, which have been found to be associated with related outcomes and may also promote sleep.

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One element of the neighborhood environment that has received relatively little attention in sleep research is green space. Green space has been positively related to many health outcomes, including some with established relationships to sleep and sleep quality such as improved mental health. The positive impacts of green space include enhanced health-promoting behaviors, such as physical activity and social engagement.^{8–10} Green space can also protect from air pollution, extreme temperature, and noise pollution.⁸ Additionally, as previously mentioned, mental health benefits such as stress reduction and mental fatigue reduction—potentially via attention restoration—are positively associated with exposure to green space including tree cover and other forms of vegetation.^{8,11} Depression and anxiety reductions, too, may be attributable to neighborhood green space.¹²

However, to our knowledge, only 2 studies have examined the role of neighborhood green space in impacting sleep outcomes. The first showed that reduced green space was associated with reduced sleep duration among >44-year-old Australian adults.⁹ A second study, which analyzed US citizens at a county level, showed those exhibiting 21–29 days per month of insufficient sleep had lower odds of green space access than those who reported less than 1 week of insufficient sleep per month.¹³ Additional work is needed to determine if sleep duration and quality are associated with green space and whether findings are consistent across multiple populations and contexts.

Beyond green space, other aspects of the neighborhood built environment, including noise (unwanted sound), have been shown to affect sleep outcomes. Notably, neighborhood sound levels—although intuitively related to sleep quality and quantity—have received little attention in empirical research; this is of interest given that noise is thought to impact sleep, green space is protective against noise pollution, and total sound affecting an individual may include both human-made and natural sounds.^{8,14} Previous research has assessed the associations between neighborhood noise and sleep outcomes. Residents in neighborhoods with high perceived noise levels report poorer physical health that is mediated by low sleep quality.¹⁵ Neighborhoods with high human-made sound (from traffic, neighbors, and crowding) may prevent residents from initiating and maintaining sleep.¹⁵ Decibel levels associated with adverse outcomes have been proposed; among European populations, exposure to sound of <40 dB has been determined to have no significant negative biological effects; 40–55 dB causes a sharp increase in negative health effects, especially in vulnerable populations; >55 dB causes annoyances in most of the population and is associated with a high frequency of adverse outcomes (eg, cardiovascular disease).¹⁶ Few population-based studies have examined these associations in the United States.

For a complete understanding of sleep, it must be conceptualized as a construct that includes both sleep quality and quantity while controlling for objective demographic and socioeconomic measures.^{17–19} Excess sleep (>9 hours a night), habitual short sleep duration (<6 hours a night), and low sleep quality have been independently associated with negative health outcomes.^{5,20–27} In the present investigation, neighborhood levels of green space and sound, and 3 sleep outcomes—duration (weekday, weekend) and quality—are studied. We hypothesize that, after controlling for confounders, individuals living in areas with higher levels of neighborhood green space and lower levels of sound will experience significantly better sleep, including higher sleep quality and more adequate sleep durations (7–8 hours).

Methods

Survey of the Health of Wisconsin

This analysis uses data from the Survey of the Health of Wisconsin (SHOW). SHOW is an ongoing survey that began in 2008, which is

modeled after National Health and Nutrition Examination Survey and designed to collect information from a representative sample of Wisconsin residents. The information included in the SHOW database includes surveys, physical examinations, and biospecimens.⁸ All participant records are geocoded to address and census block group (CBG) level to enable the linkage of SHOW data with other sources of neighborhood level information.²⁸

Study participants

Participants are noninstitutionalized and non-active-duty adult (21–74 years old) civilians from randomly selected households. Random selection includes a 2-stage probability-based cluster sampling approach stratified by region and poverty level.²⁸ Since the start of the program in 2008, sample sizes have increased from 400 to more than 1000 participants per year.^{8,29} The present study uses data from 2008 to 2013, including a total sample size of 2712 adults with complete data for both exposures and outcomes of interest.

Outcome measures

Sleep duration and sleep quality

Sleep duration was assessed for respondents who were employed, were in school, or had a varying sleep schedule by self-reported number of hours of sleep they achieved per night on an average weekday and weekend. Retired and unemployed persons without a varying sleep schedule were asked how many hours per night on average they slept. Sleep quality was assessed by asking respondents, “Over the past month, how would you rate your sleep quality overall?” Responses were scaled (excellent, very good, good, fair, and poor).

Neighborhood green space and sound level

US CBGs (defined on average having 600–3000 people) were used as the sampling units for SHOW data collection and adopted as the neighborhood definition in this study. Neighborhood greenspace was measured as the percent tree canopy per block group using information from the National Land Cover Database (NLCD). The NLCD is the most recent data available on the Wisconsin tree canopy (2011) that can be used to delineate trees as a source of greenness compared to other sources such as agriculture or other types of vegetation. We opted for a tree canopy-based measure, as percent tree canopy has a clear implication for neighborhood-level interventions (eg, the planting of trees).

Sound levels were also assessed, via data from the US National Park Service, which created a georeferenced map of sound levels across the United States, using the Random Forest models done by Breiman.¹⁴ The Random Forest models are the basis for the mapping of expected sound levels in existing conditions and with no human activity. A map of the sound produced solely by human activity was also derived by the US National Park Service by deriving the difference between nature's sounds and actual sound level of the United States with human presence.¹⁴ This map was established to understand relationships between sound and other variables in nature. Sound levels were measured in decibels exceeded half of the time on an average summer day in the geographic area being measured (L50 dBA sound pressure level, dBA re 20 μ Pa).

Figure 1 displays CBGs and whether their proportion tree canopy (from the National Land Cover Database) is above (green) or below (blue) 10%. The figure shows urban areas (ie, Southcentral, Southeast, and Northeast Wisconsin) having lower proportions of tree canopy.

Figure 2 displays CBGs and total sound (from the US National Park Service). Total sound level includes nature sound and human synthesized sound. The figure shows urban CBGs having higher decibel levels (>50 dBA) than those with lower populations.

Figure 3 displays CBGs and human only sound (from the US National Park Service). Human-only sound level excludes nature's

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