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Sleep insufficiency and the natural environment: Results from the US Behavioral Risk Factor Surveillance System survey

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ABSTRACT

Background. Exposure to the natural environment may improve health behaviors and mental health outcomes such as increased levels of physical activity and lower levels of depression associated with sleep quality. Little is known about the relationship between insufficient sleep and the natural environment.

Purpose. To determine whether exposure to attributes of the natural environment (e.g., greenspace) attenuates the likelihood of reporting insufficient sleep among US adults.

Methods. Multiple logistic regression models were used to explore the association between self-reported days of insufficient sleep (in the past 30 days) and access to the natural environment in a multi-ethnic, nationally representative sample (n = 255,171) of US adults ≥18 years of age enrolled in the 2010 Behavioral Risk Factor Surveillance System.

Results. Using 1-to-6 days of insufficient sleep as the referent group for all analyses, lower odds of exposure to natural amenities were observed for individuals reporting 21-to-29 days (OR = 0.843, 95% confidence interval (CI) = 0.747, 0.951) of insufficient sleep. In stratified analyses, statistically significant lower odds of exposure to natural amenities were found among men reporting 7-to-13-days (OR = 0.911, 95% CI = 0.857, 0.968), 21-to-29-days (OR = 0.838, 95% CI = 0.759, 0.924), and 30-days (OR = 0.860, 95% CI = 0.784, 0.943) of insufficient sleep. Greenspace access was also protective against insufficient sleep for men and individuals aged 65+.

Conclusions. In a representative sample of US adults, access to the natural environment attenuated the likelihood of reporting insufficient sleep, particularly among men. Additional studies are needed to examine the impact of natural environment exposure on sleep insufficiency across various socio-demographic groups.

Introduction

Adequate sleep has been touted as a critical component of optimal health (Colten and Altevogt, 2006). Individuals attaining adequate or sufficient sleep have been shown to have better cardio-metabolic profiles (Grandner et al., 2012; Cappuccio et al., 2011), functional capacity (Brimah et al., 2013), lower risk of overweight or obesity and death (Jean-Louis et al., 2014; Buxton and Marcelli, 2010; Kripke et al., 2002), compared to individuals experiencing inadequate or insufficient sleep. In spite of the well-documented benefits of adequate sleep for overall health, many US adults do not meet the recommended 7–8 h of sleep at night (Perry et al., 2013). Several population-based studies indicate that approximately 40% of US adults sleep less than 7 h daily (Centers for Disease Control and Prevention, 2011a; Centers for Disease Control and Prevention, 2011b). In addition to sleep disorders (Colten and Altevogt, 2006), socio-environmental and lifestyle factors such as living in an impoverished neighborhood (Hale and Do, 2007; Hale et al., 2010), shift work (Berkmn et al., 2010; Colten and Altevogt, 2006), lower physical activity levels (McClain et al., 2014), and depression are associated with curtailed sleep (Colten and Altevogt, 2006).

One environmental factor that has received less attention in sleep studies is exposure to the natural environment or "natural amenities" — the "physical characteristics of an area that may enhance the location as a place to live" (USDA Economic Research Service Natural Amenities Scale, 2012). Specific features of an area that may improve health behaviors and mental health outcomes related to sleep duration and

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quality include access to greenspace, oceanfront or other bodies of water (blue space), as well as sunlight exposure, and temperature. Greater accessibility to green landscapes has been associated with higher levels of physical activity (Coutts et al., 2013; Grigsby-Toussaint et al., 2011), which correlates to beneficial sleep patterns (Brand et al., 2010; Ueno et al., 2009). Access to greenspace has also been shown to confer benefits for mental health (Astell-Burt et al., 2013a), including improving cognitive function and reducing anxiety disorders that may result in insufficient sleep (Wells, 2002; Kuo and Taylor, 2004; Nutsford et al., 2013; Vaessen et al., 2014). Among others, environmental factors such as light and thermal environments, as well as access to water, play a pivotal role in shaping human sleep.

Turning to specific aspects of the natural environment, Wheeler et al. (2012) found a gradient of increasing self-reported "good" health with increasing residential proximity to the coast in England (Wheeler et al., 2012). Since sleep is considered one of the pillars of good health (Buxton et al., 2014), residing in areas with easy access to oceanfront or bodies of water may support good sleep habits. Alternatively, access to water may enhance health because it increases physical activity.

The thermal environment, which is important for setting our sleep/wake cycles (Gilbert et al., 2004), is influenced by ambient temperature (Okamoto-Mizuno and Mizuno, 2012). Exposure to extremes of the temperature spectrum that is not habitual where the body has an opportunity to adjust, disrupts various stages of rapid eye movement and slow wave sleep cycles, in addition to changes in heart rate (Okamoto-Mizuno and Mizuno, 2012; Okamoto-Mizuno et al., 1999). Humid conditions, in particular, increase the propensity for wakefulness (Okamoto-Mizuno and Mizuno, 2011), potentially placing individuals who live in areas with higher temperatures at increased risk for insufficient sleep.

Light is the pervasive and prominent zeitgeber (time giver) to resetting biological rhythms (Hollwich, 1979; Lewy et al., 1980; Wetterberg, 1994; Brzezinski, 1997). Light also plays a critical role in modulating sleep patterns and mood (Dumont and Beaulieu, 2007; Partonen and Pandi-Perumal, 2009). Several studies have shown that infants exposed to more natural light during the day sleep better at night, and light influences the sleep -wake cycle in adulthood as well (Harrison, 2004; Mongrain et al., 2006). At the other end of the life course, elderly individuals are more likely to have sleep disorders due to limited exposure to daytime light (Mishima et al., 2001 Jan; Shochat et al., 2000). Additionally, the influence of light exposure on mood is also evident among individuals with seasonal affective disorder, where lower exposure to light during winter months may reduce the production of melatonin via the pineal gland (Kasper et al., 1989 Sep; Wehr et al., 2001). Notably, high exposure to light at night due to shift work may result in adverse health outcomes such as certain forms of cancer, possibly due to the reduction in the secretion of melatonin (Schernhammer and Schulmeister, 2004). Thus, exposure to light during daily periods that may not be optimal for the sleep–wake cycle can result in circadian misalignment and increase the risk of sleep disturbances and other adverse health outcomes.

Although various aspects of the natural environment have been shown to influence sleep patterns, few studies have examined these relationships in large population-based samples in the US. The purpose of this study was to investigate the relationship between exposure to various attributes of the natural environment and *sleep insufficiency*. We hypothesize that individuals with higher exposure to positive attributes of the natural environment will be less likely to report insufficient sleep.

Methods

The primary data source for this study was derived from the 2010 Behavioral Risk Factor Surveillance System (BRFSS), a yearly, randomized telephone survey of behavioral risk factors among US adults ≥18 years of age (Centers for Disease Control and Prevention, 2013). A multi-ethnic nationally representative sample of adults (one per household) is sampled from all 50 states, the District of Columbia, Puerto Rico, the US Virgin Islands, and Guam to track trends in health conditions and risk behaviors in the US (Centers for Disease Control and Prevention, 2013; Mokdad et al., 2003). The BRFSS also contains geographically referenced data for participants that permit analysis across US counties to contextualize health risk. The median cooperation rate for the BRFSS in 2010 was 76.9%, while the final response rate was 54.6% (Behavioral Risk Factor Surveillance System, 2010).

To explore *sleep insufficiency*, the following question from the BRFSS was used, "During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?" Although the BRFSS sample available for analysis included 451,072 participants, after the exclusion of missing data on county codes, pregnant women, and covariates, the final sample used in the present analysis consisted of 245,531 participants.

Guided by the literature examining socio-demographic determinants of sleep patterns (Knutson, 2013), covariates in our analysis included age as a continuous variable, and categorical variables for gender, employment status, race/ethnicity (Black, White, Asian, Hispanic), level of education, number of children, smoking status, alcohol use, body mass index, asthma status, general health status, income level, disability status, physical activity and emotional support.

Natural amenities

Participants with geographically-referenced data were assigned an amenity score based on a natural amenity index developed by the USDA Economic Research Service (USDA Economic Research Service Natural Amenities Scale, 2012). The index was developed to reflect the natural landscape of counties in the lower 48 states, including varied topography such as lakes, oceanfront and climate to encompass all four seasons in the US. The index uses standardized z-scores of mean hours of sunlight, mean relative humidity, mean temperature, and proportion of water, in addition to a topography variation scale that accounts for the basic land formations (e.g., hills and mountains) in each county. The scores for average temperature, mean hours of sunlight, and mean relative humidity span a 29-year period (1941–1970). A score of 1 to 7 was then assigned to each county based on the sum of the z-scores of each of the natural amenities. A higher score corresponds to higher levels of natural amenities.

Greenspace

Access to greenspace was measured using the normalized difference vegetation index (NDVI). The NDVI is a well-established vegetation index used to measure vegetation biomass, greenness, and dominant species (Mašková et al., 2008; Williams, 2005). The NDVI scores are typically estimated based on the ratio between reflectivity in the red, and near infrared bands, where chlorophyll pigment strongly absorbs radiation in the red band, and is highly reflective in the near-infrared band (Williams, 2005). The 2006 16-day Moderate-Resolution Imaging Spectroradiometer (MODIS) data from the Global Land Cover Facility website was used to assign NDVI scores for each participant using the geographically weighted centroid of each county, as home addresses are not publicly available from the BRFSS (Global Land Cover Facility, ND). The MODIS dataset includes stretched NDVI values that range from 0 to 250 by adjusting the original NDVI values, which typically range from -1 to $+1$ using the formula (NDVI score $*$ 200) $+$ 50. Higher NDVI scores represent higher access to greenspace.

Statistical analysis

The primary independent variables were access to natural amenities and greenspace defined as continuous variables above, while *sleep insufficiency* was the primary outcome variable for all analyses. Socio-demographic, lifestyle and psychosocial control variables were examined using frequency distributions and summarized either as counts and percentages for categorical variables or as means ($\pm$standard deviations) for continuous variables. Multivariate logistic regression models were fit in STATA 12 (Stata, version 12) by categorizing sleep insufficiency into five groups as 6 days or less (referent group), 7–13 days, 14–20 days, 21–29 days, and 30 days. These categories were selected based on pre-established cut-off points for insufficient sleep using population-based US samples (Geiger et al., 2012; Centers for Disease Control and Prevention (CDC), 2008; 2009). Race, age and sex-specific differences on the influence of access to the natural environment on sleep insufficiency were also examined in stratified analyses. Sample weights developed for the 2010 BRFSS were used in all analyses (Centers for Disease Control and Prevention, 2013) to