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Original Article

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Social and built neighborhood environments and sleep health: The Hispanic Community Health Study/Study of Latinos Community and Surrounding Areas and Sueño Ancillary Studies

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Abstract

Study Objectives: To test associations between neighborhood social, built, and ambient environment characteristics and multidimensional sleep health in Hispanic/Latino adults.

Methods: Data were from San Diego-based Hispanic/Latino adults mostly of Mexican heritage enrolled in the Hispanic Community Health Study/Study of Latinos ($N = 342$). Home addresses were geocoded to ascertain neighborhood characteristics of greenness, walkability (density of intersections, retail spaces, and residences), socioeconomic deprivation (e.g. lower income, lower education), social disorder (e.g. vacant buildings, crime), traffic density, and air pollution (PM 2.5) in the Study of Latinos Communities and Surrounding Areas Study. Sleep dimensions of regularity, satisfaction, alertness, timing, efficiency, and duration were measured by self-report or actigraphy approximately 2 years later. Multivariable regression models accounting for study design (stratification and clustering) were used to examine associations of neighborhood variables with individual sleep dimensions and a multidimensional sleep health composite score.

Results: Neighborhood characteristics were not significantly associated with the multidimensional sleep health composite, and there were few significant associations with individual sleep dimensions. Greater levels of air pollution ($B = 9.03$, 95% CI: 1.16, 16.91) were associated with later sleep midpoint, while greater social disorder ($B = -6.90$, 95% CI: −13.12, −0.67) was associated with earlier sleep midpoint. Lower walkability was associated with more wake after sleep onset ($B = -3.58$, 95% CI: −7.07, −0.09).

Conclusions: Living in neighborhoods with lower walkability and greater air pollution was associated with worse sleep health, but otherwise findings were largely null. Future research should test these hypotheses in settings with greater variability and investigate mechanisms of these associations.

Key words: sleep initiation and maintenance disorders; walking; socioeconomic factors; residential segregation; traffic-related pollution; social determinants of health

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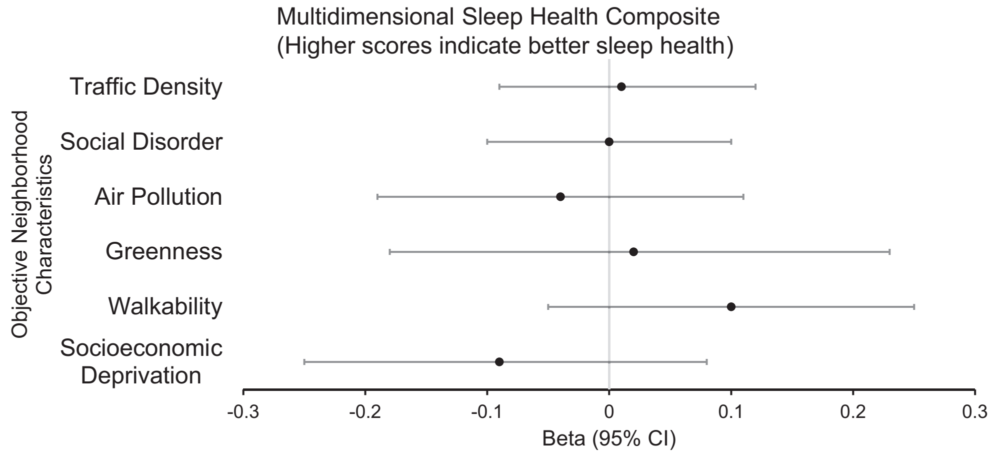
Graphical Abstract

Hispanic Community Health Study / Study of Latinos

Social and Built Neighborhood Environments and Sleep Health

Participants: 342 adults of Hispanic/Latino heritage living in San Diego county.

Multidimensional Sleep Health Composite consisted of regularity, satisfaction, alertness, timing, efficiency, and duration.



Note: Model adjusted for sociodemographic factors and health comorbidities. Betas are standardized regression coefficients.

Statement of Significance

Neighborhood environments are socio-ecological determinants of sleep health. Past studies typically relied on few, self-reported neighborhood characteristics and lacked representation of minoritized ethnic and racial groups, who often reside in segregated neighborhoods with unique sociocultural components that may shape associations with sleep. This study collected multiple objective social, built, and ambient neighborhood environment exposures. Multidimensional sleep health indicators were measured using actigraphy and validated questionnaires. The current sample was adults of majority Mexican heritage in San Diego County. Associations between neighborhood characteristics and sleep health were mostly null, but some modifiable neighborhood characteristics were linked to poorer sleep, which may have implications clinically or for policy efforts. Further research regarding mechanisms of associations is needed.

Introduction

Poor sleep quality and quantity have been associated with increased premature mortality [1, 2] and worse cardiometabolic health [3–5]. Grandner et al. posited a social-ecological model that organizes the determinants of sleep into nested ecological levels and highlights the roles of social determinants on the microsystem (individual), mesosystem (social), and macrosystem (societal) levels [1]. Individual factors including sociodemographic characteristics (e.g. employment status, income, and level of education) and health behaviors and indicators have been correlated with short and long sleep durations [6–8]. Race and ethnicity-related differences in sleep health have been identified [7, 9, 10]. These individual differences are interpreted in the context of socio-ecological factors on the community level, including one's neighborhood environment. The neighborhood environment refers to built, social, and ambient characteristics of communities, including walkability, greenness, traffic density, socioeconomic deprivation, social disorder (i.e. features illustrating a lack of social control or respect, such as crime or vacant buildings), and air pollution, which may contribute to sleep health through stress [8], emotional well-being [11], physical activity [12, 13], and inflammatory or allergic pathways [14].

Billings et al.[15] expanded on the socio-ecological model in their model of the environment and sleep (see Figure 1, adapted model) [15]. They situate neighborhood environmental factors downstream from residential segregation at the societal level to influence sleep directly and indirectly [15]. The neighborhoods of residence of people of color tend to have higher levels of socioeconomic deprivation (e.g. lower income, lower education), fewer health-promoting community resources, and greater exposure to traffic and air pollutants, as an effect of historical and ongoing structural inequities and discriminatory practices in rental and housing markets and in transportation infrastructure [16]. Hispanic/Latino adults are disproportionally impacted by poor sleep quality and short sleep duration relative to non-Hispanic White adults [7, 9, 10]. A better understanding of relationships between neighborhood environments and sleep health in Hispanic and Latino populations may elucidate how their unique environmental and sociocultural contexts may impact their sleep and point toward new promising interventions.

In the Hispanic Community Health Study/Study of Latinos (HCHS/SOL), a prospective cohort study of more than 16 000 Hispanic/Latino adults from four US communities, perceptions of living in a high-crime neighborhood were associated with greater

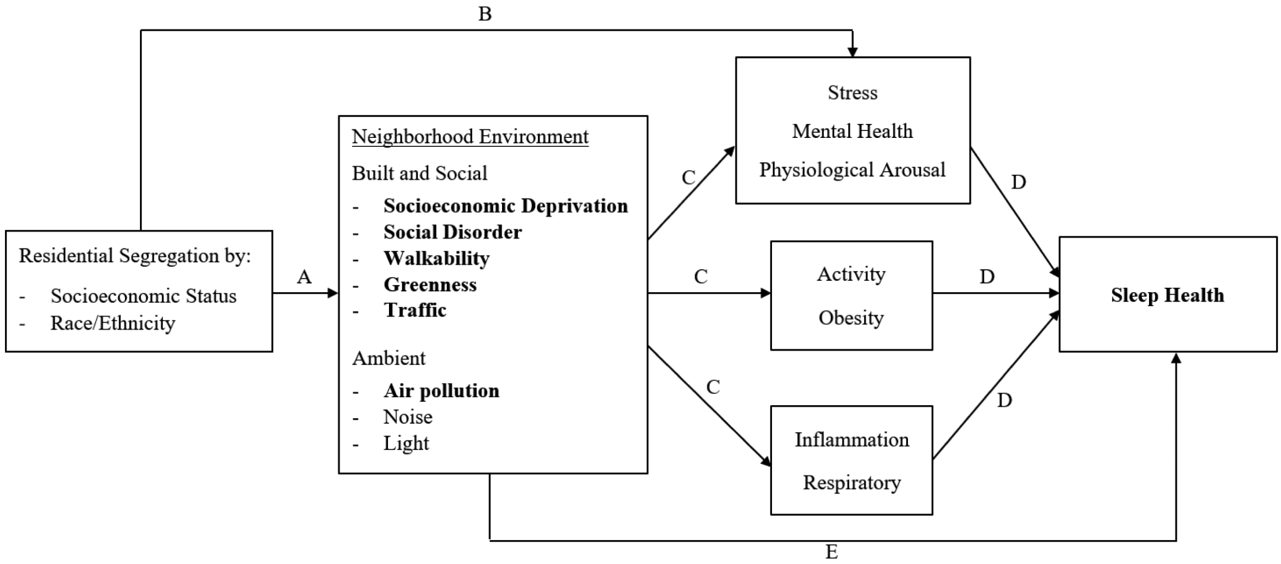


Figure 1. Note. Bold font indicates variables measured in the current study. The model posits that residential segregation impacts one's neighborhood environment (path A) and psychosocial health (path B). The neighborhood environment, in turn, is expected to have both indirect (paths C and D) and direct (path E) associations with sleep health. The current study tested direct associations in path E. Proposed mediators of associations include psychosocial, physical activity, and inflammatory factors.

odds of short sleep duration (<6 hours), and prevalence of insomnia was greater in those who perceived living in a noisy neighborhood (compared to non-noisy) [17]. The prior analysis began to clarify how perceived neighborhood environments relate to sleep in Hispanic/Latino adults. However, some studies have identified differential associations of neighborhood characteristics with sleep depending on measurement method (self-reported or objective) [18]. Self-reported perceptions of the neighborhood environment may be influenced by recall bias and lack of precision compared to objective measures. Additionally, findings from objective assessments of neighborhood features may more easily translate to interventions targeted at such features. Thus, further examination of relationships between a broader range of neighborhood characteristics and sleep is needed using objective measures of neighborhoods.

The current study aimed to address this gap and build from Billing et al.'s model [15] of the environment and sleep by examining neighborhood-level correlates of sleep in Hispanic/Latino adults from the San Diego site of the HCHS/SOL and its Community and Surrounding Areas (SOL CASAS) and Sueño ancillary studies (see Figure 1). Specifically, the current manuscript examined relationships between multiple objectively measured social and built neighborhood environmental variables and both self-reported and actigraphy-measured sleep characteristics. We hypothesized that objectively defined neighborhood features indicating disadvantage, including socioeconomic deprivation, social disorder, air pollution, and traffic, would be associated with poorer multidimensional sleep health. Additionally, we hypothesized that neighborhood assets such as walkability and greenness would be protective in relation to these indicators of sleep health.

Methods

Study design and sample

HCHS/SOL is a population-based prospective cohort study of adults aged 18–74 years at enrollment, who self-identified as Hispanic/Latino, and were recruited from four US field centers. Baseline (visit 1) data were collected between 2008 and 2011. The complex survey design allowed for a diverse sample, and sampling weights were adopted to ensure effect estimates represented the target population of non-institutionalized Hispanic/Latino adults in the four recruitment communities [19, 20]. The Sueño ancillary study (2010–2013) enrolled a subset of the HCHS/SOL cohort who were within 30 months of their visit 1 date, between 18 and 64 years old, and free of narcolepsy, severe obstructive sleep apnea, and use of positive airway pressure therapy [21]. The SOL CASAS ancillary study geocoded visit 1 addresses of HCHS/SOL participants living in the San Diego area [22]. The analytic sample of the current study included 342 participants from the San Diego field center with neighborhood data from SOL CASAS and valid sleep data from Sueño. All participants provided written consent and the protocols were approved by the institutional review boards at all participating institutions.

Neighborhood environment characteristics

Based on geocoded addresses, an 800-meter circular radial buffer was created using geographic information systems software and reflected a reasonable walking distance of about 10 minutes around the home [23–26]. Built, social, and ambient environmental variables in that buffer were ascertained using publicly available data sources. *Socioeconomic Deprivation* was derived using principal components analysis, based on variables reflecting the relatively low social and economic position of a neighborhood (see Table 1). *Social Disorder* was also derived using principal components analysis, based on variables associated with neighborhood distrust (see Table 1) [27, 28]. Both variables derived using principal components analysis were calculated using all census block groups in San Diego County and one-factor solutions were determined to be the best fit for the data. *Walkability* was computed from the sum of Z-scores of densities of intersections, retail spaces, and residences, following the methodology of a well-validated index that has been linked to walking trip choices [29, 30]. *Greenness* was ascertained from the normalized difference vegetation index, an index calculated

Table 1. Neighborhood Environment Composite and Index Variables

Composite or index	Description and sources
Socioeconomic deprivation	Principal components analysis (PCA) was used to create this composite, based on the following variables: Percent of adults 25 years or older with no high school diploma; percent of adults unemployed; percent of households that rented; percent of households that are defined as crowded (using standard Census American Community Survey and US Department of Housing and Urban Development definition of more than one person per room); percent of households living below the poverty line; percent of female-headed households with dependent children; percent of households on public assistance; and percent of population on public health insurance. Data were obtained from the Census (2010) and American Community Survey 5-year estimates (2009–2013). Data were derived from the census block group level and then weighted averages were calculated from block groups that were present within the individualized buffer. Variables were chosen that were commonly used metrics for socioeconomic deprivation and were removed if they did not load into the total component. A 1-component solution was determined to be the best fit for this data (eigenvalue = 4.78; variance accounted for = 53%), with all factors highly loading.
Walkability	Index computed as summed z-scores of the density of intersections, retail spaces, and residences. Data were obtained from the San Diego Association of Governments (SANDAG) 2008 or 2013 estimates, San Diego's regional planning agency that hosts public spatial data.
Greenness	The Normalized Difference Vegetation Index (NDVI) is an index calculated using composite Landsat imagery obtained from Google Earth Engine in 2010. This index represents the difference between light that vegetation reflects (i.e. near-infrared) and light that vegetation absorbs (i.e. red light) to quantify the amount and density of trees and vegetation. NDVI scores range from −1 to + 1, with higher levels reflecting greater density of vegetation.
Air pollution	The annual mean concentration of particulate matter 2.5 (PM 2.5, average of quarterly means, µg/m3), over 3 years (2009–2011) was calculated to reflect air pollution. These data were derived from the CalEnviroScreen tool which publishes pollution indicators drawn from the Environmental Protection Agency and other data sources. The California Air Resources Board has a network of 18 air quality monitoring sites throughout San Diego County which were used to quantify this exposure, along with satellite observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite.
Social disorder	Principal components analysis (PCA) was used to create this composite, based on the following variables: Percent of households that are vacant; percent of land that is vacant (vacant land and households determined by San Diego Association of Governments (SANDAG) land parcel classifications); part 1 crime (e.g. aggravated assault robbery, forcible rape) per 10 000 residents; part 2 crime (e.g. fraud, other sex crimes, and vandalism) per 10 000 residents; liquor stores selling to-go alcohol per 10 000 residents. Data were obtained from the 2010 Census, the County of San Diego's Automated Regional Justice Information System (2012), SANDAG (2008), and the California Alcohol and Beverage Control Agency (2012). Data were derived from the census block group level and then weighted averages were calculated from block groups that were present within the individualized buffer. In the PCA, a 1-component solution was determined to be the best fit for this data (eigenvalue = 1.88; variance accounted for = 38%), with all factors highly loading.
Traffic density	The sum of traffic volumes (average count of vehicles per meter per day) is adjusted by road segment length (vehicle kilometers per hour) divided by the total road length (kilometers) within 150 meters of the census tract boundary. Data were obtained from the CalEnviroScreen tool which publishes traffic indicators drawn from the TrafficMetrix® Traffic Count Database in 2004. For data on traffic volumes for vehicles along the US-Mexico border, data were obtained for the Tijuana area from SANDAG. Data were derived from census tract level and then weighted averages were calculated from tracts that were present within the individualized buffer.

MODIS, Moderate Resolution Imaging Spectroradiometer; NDVI, normalized Difference Vegetation Index; PCA, Principal Components Analysis; PM 2.5, Particulate Matter 2.5; SANDAG, San Diego Association of Governments.

from 2010 annual composite average satellite imagery via Landsat and Google Earth Engine (Google, 2017; Mountain View, CA) representing the difference between light that is reflected by and absorbed by vegetation (i.e. near-infrared and red light) to quantify the density of trees and other vegetation [31]. *Air pollution* was defined as the annual mean concentration (average of quarterly means) of particulate matter 2.5 (PM 2.5) over 3 years. PM 2.5 consists of fine particles or droplets suspended in the air ≤ 2.5 micrometers in width that are often formed as part of combustion processes (e.g. car exhaust, factories). Due to their size, PM 2.5 can travel deeply into the respiratory tract and reach the lungs and has been linked with poorer sleep quality [14, 32], as well as poorer pulmonary and cardiovascular health. These data were derived from the California Air Resources Board which has a network of 18 air quality monitoring sites throughout San Diego County and from satellite monitoring. *Traffic Density* was the sum of traffic volumes (average count of vehicles per meter per day) adjusted by road segment length (vehicle kilometers per hour) divided by the total road length (kilometers) within 150 meters of the census tract boundary. Air pollution and traffic datapoints were from the CalEnviroScreen 2.0 tool [33]. See Table 1 for detailed information regarding the neighborhood variable sources. Data were derived at the census tract or block group level and then weighted averages were calculated from tracts or block groups that were present within the individualized circular buffer.

Sleep

The Ru-SATED model [34] of sleep health emphasizes the importance of measuring and promoting *multidimensional* sleep health, rather than focusing on sleep disorders or deficiencies in one area. This model defines multidimensional sleep health as the measured characteristics across six dimensions: regularity, satisfaction, alertness, timing, efficiency, and duration. Reflecting these dimensions, our sleep outcomes included a composite of these characteristics (i.e. interdaily stability, insomnia symptoms, daytime sleepiness, midpoint, wake after sleep onset (WASO), and duration), as well as each component individually. Insomnia symptoms were measured by the insomnia severity index, a seven-item instrument that assesses the nature, severity, and impact of insomnia (range: 0 to 28) [35]. Daytime Sleepiness was measured by the Epworth Sleepiness Scale, an eight-item questionnaire that measures excessive sleepiness in several daytime situations (range: 0 to 24) [36]. Scales have been validated in English and Spanish [37, 38] and were administered in the participant's preferred language.

Actigraphy was used to ascertain interdaily stability, midpoint, WASO, and duration. Participants were instructed to wear an Actiwatch Spectrum (Philips Respironics, Murrysville, PA) on the non-dominant wrist for 7 days and nights and complete a brief daily sleep diary. Raw sensor and sleep diary data were scored if there were at least 5 valid days of data using an integrated, standardized algorithm [21]. Interdaily stability was a measure of regularity of sleep–wake patterns across 7 days [39, 40]. It is calculated as the proportion of the total variance in sleep–wake status (dichotomized) at a particular epoch explained by the clock time. Interdaily stability can range from 0 (the clock time explains none of the variance in sleep–wake status) to 1 (the clock time explains all of the variance). These data were available in the subset of participants ($n = 243$) that had 7 days of valid actigraphy data. Midpoint was the clock time midway between sleep onset and offset. Sleep midpoint was converted to minutes before/after 4:00 AM (approximate median midpoint of the sample) to allow for linear analysis. WASO was the amount of time in minutes awake between sleep onset and offset in the main sleep period. Duration was the total time in minutes spent asleep between sleep onset and offset during the main sleep period. To produce an overall sleep health score, each component was dichotomized with 0 indicating poor sleep health and 1 indicating good sleep health (See Table 2 for the cutoffs) and then summed, with greater values indicating better sleep health. Cutoffs were chosen based on prior research and to have roughly similar proportions of "good" and "poor" ratings across sleep health dimensions [41–44].

Covariates

Self-reported sociodemographic and health characteristics were entered into models as covariates, including age, sex (male; female), education (no high school diploma/GED; high school diploma/GED or higher), household income (less than $10 000; $10 001–$15 000; $15 001–$20 000; $20 001–$25 000; $25 001–$29 999; $30 000–$40 000; $40 001–$50 000; $50 001–$75 000; $75 001–$100 000; and more than $100 000), place of birth/duration of residence in US 50 states/D.C. (born in the US 50 states/D.C.; less than 10 years living in US 50 states/D.C.; greater than 10 years living in US 50 states/D.C.), employment status (employed full-time; employed part-time; not employed; retired), work schedule (night/rotating shift work; any other shift) [45] and comorbidities. The comorbidity index counted 1 point each for prevalent diabetes, cardiovascular disease, obstructive lung disease, and cancer [46], defined by appropriate laboratory data as available, or self-report.

Statistical analysis

Descriptive statistics and correlations among neighborhood exposures were performed in IBM SPSS Statistics Version 28 (IBM, Inc., Armonk, NY). The maximum likelihood robust estimation procedure in MPlus Version 8 [47] was used to test study hypotheses. maximum likelihood robust is a full-information maximum likelihood approach in which model parameters and standard errors are estimated using both complete and partial cases and produces unbiased estimates under various missing data conditions [48]. Linear regression models accounted for study design (stratification and clustering) and controlled for the influence of possible confounding sociodemographic factors and health variables as described above. Models were fit to examine relationships between built, social, and ambient neighborhood environments and the composite sleep health score and each of its individual component characteristics. Neighborhood independent variables were z-score standardized (Mean = 0, $SD = 1$) to aid interpretation, and categorical covariates were scaled as nominal.

The first set of models (model 1) was fit with the covariates and one neighborhood exposure variable entered individually. A second set of models (model 2) entered the covariates and all six of the neighborhood variables jointly into a single model. Both unstandardized (B) and standardized (β) regression coefficients are reported. Betas are used as an indicator of effect sizes, with $\beta = 0.1$ considered a small effect size, 0.2 as small-to-moderate, and 0.3 as moderate [49]. Holm's adjustment was used to account for the evaluation of multiple comparisons and possibility of statistical significance due to chance alone by applying a more stringent P-value as the number of comparisons increased [50]. To separate the potential impact of sleep-disordered breathing or sleep aid medication on sleep outcomes, sensitivity analyses were

Table 2. Sleep Health Cutoff Values

Component	Metric	Cutoff	Proportion good	Proportion poor
Regularity	Interdaily stability	≥0.739 = good <0.739 = poor	74.9%	25.1%
Satisfaction	Insomnia severity index	<10 = good ≥10 = poor	74.5%	25.5%
Alertness	Epworth Sleepiness Scale	≤10 = good >10 = poor	88.5%	11.5%
Timing	Main sleep midpoint	2:00 – 4:00 am = good <2:00 or > 4:00 am = poor	63.7%	36.3%
Efficiency	Wake after sleep onset (WASO)	<60 minutes = good ≥60 minutes = poor	74.6%	25.4%
Duration	Main sleep duration	≥6 hours = good <6 hours = poor	85.1%	14.9%

conducted including apnea–hypopnea index and the use of sleep aid medication as additional covariates. Due to the influence of having a night or rotating shift work schedule on sleep [45], sensitivity analyses were also conducted excluding participants with these schedules.

Results

Descriptive statistics

The study sample was 43.9 ± 11.8 years old on average, 66.1% female, and 99.7% of Mexican heritage (see Table 3). About one-third (34.8%) obtained less than a high school education and 72.3% had a household income of $40 000 or less. About half (51.3%) were employed and of those, 6.9% had a night or rotating shift work schedule. Sleep duration on average was 6.9 ± 1.0 hours.

Correlations among neighborhood exposures

As shown in Table 4, socioeconomic deprivation had a positive correlation with walkability ($r = 0.53$) and a negative correlation with greenness ($r = -0.66$). Greenness was negatively correlated with walkability ($r = -0.66$) and positively correlated with air pollution ($r = 0.51$). Other correlations were statistically significant but of smaller magnitude.

Multidimensional sleep health composite

No neighborhood characteristic was statistically significantly associated with the composite sleep health indicator (all *p*s > 0.05, see Table 5).

Sleep health components

Associations between neighborhood characteristics and sleep health components are shown in Table 6. In model 1, a 1-standard deviation increase in air pollution was associated with later sleep midpoint ($B = 9.03$, 95% CI: 1.16, 16.91). The association remained of similar magnitude but was no longer statistically significant after adjustment for the other neighborhood variables in model 2. Greater social disorder was associated with an earlier sleep midpoint in models 1 and 2 (model 2 B = −6.06, 95% CI:−11.32, −0.79). Lower walkability was associated with greater WASO in Model 2 ($B = -3.58$, 95% CI: −7.07, −0.09). These findings did not remain significant after adjustment for multiple comparisons using more stringent *P*-values. No significant relationships were found between neighborhood characteristics and interdaily stability, insomnia symptoms, daytime sleepiness, or sleep duration.

Sensitivity analysis

In sensitivity analyses including apnea–hypopnea index and the use of sleep aid medications as additional covariates, results were not materially changed from primary analyses. After adjusting for apnea–hypopnea index and the use of sleep aid medications, the association of walkability with WASO was slightly reduced in magnitude ($B = -3.41$, 95% CI: −6.83, 0.00, $p = 0.05$).

In sensitivity analyses excluding the 12 night/rotating shift workers, greater air pollution ($B = 2.66$, 95% CI: 0.31, 5.02) and traffic density ($B = 1.95$, 95% CI: 0.04, 3.86) were associated with greater WASO. Otherwise, results were very similar in direction and magnitude to those from primary analyses.

Table 3. Descriptive Statistics for Sociodemographic Factors and Sleep Characteristics, HCHS/SOL (San Diego Only), SOL CASAS and Sueño ($N = 342$)

	n **(%) or M (SD)**
Sociodemographic factors	
Age (years)	43.9 (11.8)
Female	226 (66.1%)
Mexican heritage	341 (99.7%)
Less than high school education	119 (34.8%)
Household income	
< $10 000	35 (10.7%)
$10 001–$20 000	83 (25.4%)
$20 001–$40 000	118 (36.2%)
$40 001–$75 000	69 (21.1%)
> $75 000	21 (6.5%)
Place of birth/duration of US residence	
Born in US 50 states/D.C.	75 (21.9%)
Born outside US 50 states/D.C. and duration of US residence ≥ 10 years	206 (60.2%)
Born outside US 50 states/D.C. and duration of US residence < 10 years	61 (17.8%)
Employment status	
Employed full-time	113 (33.1%)
Employed part-time	62 (18.2%)
Not retired and not employed	160 (46.9%)
Retired	6 (1.8%)
Work schedule of those employed	
Day, afternoon, split, or irregular shift	161 (93.1%)
Night or rotating shift	12 (6.9%)
Comorbidity count (range = 0 to 4)	0.5 (0.6)
Sleep aid medication use ≥ 3 times per week	9 (2.7%)
Sleep characteristics	
Multidimensional sleep health score (range = 0 to 6)	4.6 (1.2)
Interdaily stability ($n = 243$)	0.79 (0.13)
Insomnia severity index ($n = 341$)	6.7 (6.0)
Epworth Sleepiness Scale ($n = 338$)	4.9 (4.1)
Sleep midpoint (time in hh:mm, $n = 342$)	3:24 (1:21)
Wake after sleep onset (WASO, minutes, $n = 342$)	48.4 (20.6)
Sleep duration (hours, $n = 342$)	6.9 (1.0)

HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SOL CASAS, Study of Latinos Community and Surrounding Areas Study.

Discussion

This study investigated objective social, built, and ambient environment characteristics individualized to participants' home neighborhoods in relation to multiple dimensions of self-reported and actigraphy-assessed sleep health in a Hispanic/Latino sample. Analyses revealed mostly null associations between neighborhood indicators and sleep health. The few significant associations in primary analyses included an association between greater air pollution and later sleep timing, but this did not remain significant after adjustment for the other neighborhood variables. Lower walkability was associated with reduced sleep efficiency after adjusting for the other neighborhood variables. There was an unexpected association between greater social disorder with

Table 4. Bivariate Correlations Among Neighborhood Variables, SOL CASAS and Sueño (*N* = 342)

	Walkability	Greenness	Air pollution	Social disorder	Traffic density
Socioeconomic deprivation	0.53***	−0.66***	−0.33***	0.01	0.42***
Walkability		−0.66***	−0.03	0.21***	−0.17**
Greenness			0.51***	−0.28***	−0.06
Air pollution				−0.13*	−0.40***
Social disorder					−0.17**
Traffic density					

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
SOL CASAS, Study of Latinos Community and Surrounding Areas Study.

Table 5. Associations Between Neighborhood Environment Characteristics and Sleep Health Composite, SOL CASAS, and Sueño (*N* = 342)

Neighborhood characteristic	Multidimensional sleep health			
	Model 1		Model 2	
	B (95% CI)	β	B (95% CI)	β
Socioeconomic deprivation	−0.04 (−0.18, 0.09)	−0.04	−0.10 (−0.29, 0.08)	−0.09
Walkability	0.05 (−0.09, 0.20)	0.04	0.13 (−0.06, 0.32)	0.10
Greenness	−0.01 (−0.14, 0.13)	−0.01	0.03 (−0.22, 0.28)	0.02
Air pollution	−0.01 (−0.11, 0.11)	−0.01	−0.04 (−0.20, 0.12)	−0.04
Social disorder	0.02 (−0.07, 0.11)	0.02	0.00 (−0.10, 0.09)	0.00
Traffic density	−0.03 (−0.12, 0.06)	−0.03	0.01 (−0.11, 0.14)	0.01

SOL CASAS, Study of Latinos Community and Surrounding Areas Study.
Model 1 includes neighborhood variables individually in separate models, and adjusts for covariates: age, sex, education, income, place of birth/duration of US residence, employment status, comorbidities, and work schedule (night/rotating shift work or not).
Model 2 includes all neighborhood variables, in one single model, and adjusts for covariates: age, sex, education, income, place of birth/duration of US residence, employment status, comorbidities, and work schedule (night/rotating shift work or not).
β are standardized coefficients and can be interpreted as effect sizes indicating the change in standard deviation units in the dependent variable per 1 standard deviation increase in the independent variable.

earlier sleep timing, which was robust to adjustment for the other neighborhood variables and consistent across sensitivity analyses. In sensitivity analyses excluding night/rotating shift workers, greater levels of air pollution and traffic density were associated with lower sleep efficiency. Observed associations were of small or small-to-moderate magnitude ($0.1 < \beta < 0.2$) [49], and did not remain significant after adjusting for multiple comparisons [50]. No associations were found between socioeconomic deprivation, greenness, or traffic density exposures with sleep outcomes in primary analyses.

Built environment characteristics such as walkability and greenness have been related to positive health outcomes including increased physical activity, healthier weight status, reduced cardiovascular risk, and greater social cohesion [11–13, 51]. In the current primary analysis, lower walkability was associated with greater WASO (i.e. lower sleep efficiency). In sensitivity analyses adjusting for apnea–hypopnea index or use of sleep aid medications the association was no longer significant. The protective association of walkability may occur through reducing sleep apnea severity, which has been shown in other multi-ethnic cohorts [52]. Past studies have shown protective effects of greenness in relation to sleep [53, 54], while the association between walkability with sleep has been mixed or negative [55]. Besides the association with WASO, there were null associations of walkability and greenness with other sleep characteristics in the current study. Features of walkable or green neighborhoods include density of population and retail spaces and green public parks or recreational spaces. While these characteristics relate to both sleep-promoting factors such as physical activity and emotional well-being, they also relate to sleep-limiting factors such as increased noise or light at night, which may result in null statistical associations if both are present. These pathways deserve further exploration in future studies.

Prior analyses with this San Diego HCHS/SOL cohort have shown that geographic information systems-derived dimensions of neighborhood socioeconomic deprivation and social disorder are risk factors for deteriorating cardiometabolic health over time [56, 57]. Exposure to self-reported high-crime (perceived as "unsafe") neighborhoods has also been associated with poorer sleep quality in an urban sample of African-American adults [58]. In the larger Sueño study, perceptions of living in a high-crime neighborhood were associated with greater risk of short sleep duration and late sleep midpoint [17]. In contrast, we found largely null associations of objectively defined social disorder (which contains measures of neighborhood crime) or neighborhood socioeconomic deprivation with sleep. It is possible that this is due to perceptions of safety differing from actual crime statistics. The one significant association was between increased social disorder with earlier sleep midpoint, which was robust to sensitivity analyses. While earlier sleep midpoint is generally thought to be indicative of better sleep health and associated with better health outcomes [59], a recent systematic review rated the quality of evidence as very low to moderate. Research in the HCHS/SOL suggests age-related differences in the health benefits of an earlier sleep midpoint, and in younger individuals, later sleep midpoint was protective for cardiometabolic health [60, 61]. Social

Table 6. Associations Between Neighborhood Environment Characteristics and Individual Sleep Metrics, SOL CASAS and Sueño (*N* = 342)

Neighborhood characteristic	Model 1											
	Regularity interdaily stability (*n* = 243)		Satisfaction insomnia severity index		Alertness Epworth Sleepiness Scale		Timing main sleep midpoint (minutes)		Efficiency wake after sleep onset (minutes)		Duration main sleep duration (minutes)	
	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β
Socioeconomic deprivation	0.00 (−0.02, 0.02)	0.00	0.24 (−0.40, 0.87)	0.04	0.15 (−0.32, 0.63)	0.04	−3.74 (−11.36, 3.87)	−0.05	0.20 (−1.95, 2.35)	0.01	−4.44 (−11.68, 2.80)	−0.08
Walkability	0.00 (−0.02, 0.02)	−0.02	−0.15 (−0.77, 0.48)	−0.02	0.11 (−0.36, 0.58)	0.03	−4.95 (−14.01, 4.11)	−0.06	−1.60 (−3.90, 0.70)	−0.08	−2.22 (−9.38, 4.94)	−0.04
Greenness	−0.01 (−0.03, 0.01)	−0.08	−0.26 (−0.74, 0.22)	−0.05	−0.26 (−0.71, 0.19)	−0.07	6.64 (−1.30, 14.57)	0.09	−0.09 (−2.60, 2.42)	−0.01	3.63 (−3.76, 11.01)	0.06
Air pollution	−0.01 (−0.02, 0.01)	−0.07	−0.32 (−0.84, 0.21)	−0.06	0.00 (−0.39, 0.38)	0.00	9.03* (1.16, 16.91)	0.13	0.17 (−1.93, 2.26)	0.01	1.85 (−3.93, 7.63)	0.04
Social disorder	0.00 (−0.02, 0.02)	0.02	−0.13 (−0.51, 0.25)	−0.03	0.19 (−0.08, 0.47)	0.06	−6.90* (−13.12, −0.67)	−0.11	0.89 (−0.74, 2.52)	0.06	0.70 (−4.90, 6.31)	0.02
Traffic density	0.00 (−0.01, 0.01)	0.03	0.19 (−0.36, 0.73)	0.03	−0.18 (−0.48, 0.11)	−0.05	−3.45 (−10.36, 3.47)	−0.05	1.24 (−0.83, 3.32)	0.07	−0.66 (−6.96, 5.65)	−0.01

	Model 2											
	Regularity interdaily stability (*n* = 243)		Satisfaction Insomnia severity index		Alertness Epworth Sleepiness Scale		Timing Main sleep midpoint (minutes)		Efficiency Wake after sleep onset (minutes)		Duration Main sleep duration (minutes)	
Neighborhood characteristic	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β	B (95% CI)	β
Socioeconomic deprivation	−0.01 (−0.04, 0.01)	−0.11	0.16 (−0.95, 1.26)	0.03	0.25 (−0.43, 0.92)	0.07	1.31 (−8.07, 10.69)	0.02	−0.06 (−2.59, 2.46)	0.00	−3.87 (−14.96, 7.23)	−0.07
Walkability	−0.01 (−0.04, 0.01)	−0.09	−0.48 (−1.53, 0.58)	−0.08	−0.37 (−1.06, 0.33)	−0.09	−8.34 (−23.86, 7.19)	−0.10	−3.58* (−7.07, −0.09)	−0.17	0.97 (−8.46, 10.40)	0.02
Greenness	−0.03 (−0.05, 0.00)	−0.20	−0.44 (−1.56, 0.68)	−0.08	−0.36 (−1.19, 0.47)	−0.09	−5.59 (−22.22, 11.05)	−0.07	−3.12 (−7.33, 1.09)	−0.16	2.01 (−8.90, 12.92)	0.04
Air pollution	0.00 (−0.02, 0.02)	0.02	−0.13 (−1.00, 0.73)	−0.03	0.16 (−0.42, 0.74)	0.05	9.82 (−3.36, 23.00)	0.14	2.32 (−0.03, 4.67)	0.13	0.69 (−6.24, 7.61)	0.01
Social disorder	0.00 (−0.02, 0.02)	−0.01	−0.17 (−0.58, 0.25)	−0.04	0.15 (−0.14, 0.44)	0.06	−6.06* (−11.32, −0.79)	−0.10	1.29 (−0.15, 2.72)	0.08	1.17 (−4.44, 6.78)	0.03
Traffic density	0.01 (−0.01, 0.02)	0.05	−0.07 (−0.72, 0.59)	−0.01	−0.25 (−0.67, 0.16)	−0.07	−2.76 (−11.75, 6.24)	−0.04	1.78 (−0.43, 4.00)	0.09	1.45 (−7.74, 10.63)	0.03

* $p < 0.05$.
HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SOL CASAS, Study of Latinos Community and Surrounding Areas Study.
Model 1 includes neighborhood variables individually in separate models, and adjusts for covariates: age, sex, education, income, place of birth/duration of US residence, employment status, comorbidities, and work schedule (night/rotating shift work or not).
Model 2 includes all neighborhood variables, in one single model, and adjusts for covariates: age, sex, education, income, place of birth/duration of US residence, employment status, comorbidities, and work schedule (night/rotating shift work or not).
β are standardized coefficients and can be interpreted as effect sizes indicating the change in standard deviation units in the dependent variable per 1 standard deviation increase in the independent variable.

cohesion is another neighborhood characteristic that has been associated with better sleep health, though it was not assessed in the current study [15]. There are other important socio-ecological environmental factors, such as those within the home, that may have a more pronounced influence on sleep quantity and quality than those on the neighborhood level. For example, the number of people and amount of noise within a home at night and whether there are childcare responsibilities are also important considerations related to one's sleeping environment that were not considered in the current study.

Adverse ambient characteristics (traffic density, pollution) have been associated with poorer sleep health in past research, in particular sleep quality [14, 15]. In the current study, those findings were not replicated in primary analyses, but when night/rotating shift workers were excluded from analyses, positive associations of air pollution and traffic density with WASO were statistically significant, in line with prior research. This suggests that the association may be diluted when the sample includes individuals who obtain their main sleep outside of nighttime. Living in areas of high traffic has been linked with greater noise exposure in the evening compared to areas without traffic [62]. In a previous study in the HCHS/SOL Sueño, self-reported exposure to noise was associated with greater insomnia prevalence, but not sleep efficiency [17]. It is possible that perception of noise may relate to broader self-reported sleep disturbances while objective traffic density may relate to greater objectively assessed sleep fragmentation. Unexpectedly, air pollution and traffic density had a moderate to large negative correlation in the current study, indicating that perhaps PM 2.5 in this area was emitted from sources other than vehicle exhaust or that it traveled from other regions. A large part of the study sample lived near the US-Mexico border, which has higher PM 2.5 concentrations than other regions of San Diego County, primarily due to emissions south of the border [63], which can travel depending on air currents, winds, and geography, while traffic is fixed to the roads. These limitations may explain the null associations that were found between air pollution and other sleep measures.

The current study has multiple strengths, including its thorough characterization of objective neighborhood characteristics in individualized buffer areas specific to one's home and the use of gold standard measures for multiple dimensions of sleep health. There are also limitations to be considered. The assessment of multiple neighborhood characteristics and multiple dimensions of sleep health led to a large number of comparisons tested, and associations did not remain significant when using Holm's adjustment [50]. Thus, associations could be due to chance and should be interpreted with caution. Standardized regression coefficients are presented to aid in interpretation of effect sizes. The sample size was modest to support all of the analyses conducted and confidence intervals around the coefficients were relatively large. We recommend future studies use larger sample sizes to allow greater measurement precision. Air pollution and traffic variables were both assessed as averages across the entire day (not only at night) over 1–3 years, and individuals were not necessarily exposed to these within the home or during the sleep period. Our assessment of the neighborhood environment focuses on macro-scale features. Specifically, our walkability measure is a well-validated index linked to walking trip choices [64], that includes the macro-scale features of residential density, retail density, and the connectivity of streets. There are also micro-scale features, which may influence walkability (e.g. sidewalk availability) that warrant future evaluation. The timing of the sleep assessment was conducted on average 2 years later than the HCHS/SOL baseline visit when the neighborhood environmental assessment occurred. Participants may have moved during that period and no longer experienced the same environmental exposures. While we know that 109 participants (32% of the current sample) moved between baseline and visit 2 of the HCHS/SOL (a 6-year time period), we do not know if this was before or after the sleep assessment, limiting our ability to conduct more nuanced sensitivity analyses. Our data indicate that many participants who moved stayed close to their original residences. We also did not assess duration of time individuals had lived in their residences prior to the baseline assessment, so degree of exposure to neighborhoods may have impacted their associations with sleep. Participants self-selected their neighborhoods, and healthier individuals of higher socioeconomic status are more likely to live in neighborhoods with more resources. Thus, interpretation of results cannot be considered causal [65]. The sample was from a small portion of San Diego County and variability in environments was limited [64, 66], which hinders the ability to detect associations. Finally, essentially all participants were of Mexican heritage (99.7%), which is helpful in characterizing associations within this group, but findings cannot be assumed to generalize to other Hispanic/Latino heritage groups or geographic locations.

Summary

Increasing evidence suggests that neighborhood social, built, and ambient environment characteristics, along with other socio-ecological determinants, are related to multiple dimensions of sleep health. Findings from the current study indicate largely null associations, except that greater walkability and lower air pollution levels were protective for some dimensions of sleep. These findings could inform future policy efforts aimed at improving health-promoting features of neighborhood environments, with an emphasis on enhancing walkability and reducing air pollution. Further research should clarify environmental determinants of sleep in Hispanic/Latino individuals (within the home or on the neighborhood level) among samples representing greater geographic and built environment variability. In future studies, it would be worthwhile to further examine these associations in Hispanic/Latino adults who face inequities in neighborhood environments and investigate differences in perceived and objective measures of neighborhood exposures in both built, social, and ambient environments. Mechanisms of environmental features that were previously associated with sleep health also warrant investigation to determine if they may have varying influences by race and ethnicity.

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Data Availability

The study website https://sites.cscc.unc.edu/hchs/ provides detailed information on data availability.

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