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Original Article

Original Article

Relationships between neighborhood social stressors and sleep among Jackson Heart Study participants: mediation through physical activity and psychosocial stressors

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Abstract

Study Objectives: To examine associations between perceived neighborhood social environment (PNSE) and sleep, mediated by physical activity (PA) and psychosocial stressors.

Methods: A sample (n = 4705) of African Americans (mean age 55.0 years; 63.4% female) enrolled in the 2000–2004 Jackson Heart Study (JHS). Four self-reported sleep outcomes were analyzed: sleep duration (minutes/night), sleep quality (high/low), short sleep (short ≤ 6 h vs recommended = 7–8 h), and long sleep (long ≥ 9 h vs recommended). PNSE factors included violence (e.g. robbery), problems (trash/litter), and social cohesion (trusting neighbors). PA and psychosocial stressors (lifetime and everyday discrimination, perceived stress, and depressive symptoms) were tested as mediators. With bootstrap-generated 95% bias-corrected confidence intervals (BC CIs), linear regression was used to test for mediation adjusting for covariates.

Results: Neighborhood violence and problems were associated with sleep duration, mediated through PA (B = –1.97, 95%*BC CI* = –3.76, –0.60; B = –1.23, 95%*BC CI* = –2.55, –0.27, respectively), lifetime discrimination (B = 2.61, 95%*BC CI* = 0.93, 4.80; B = 2.25, 95%*BC CI* = 0.93, 3.94), perceived stress (B = –3.08, 95%*BC CI* = –6.20, –0.41; B = –2.17, 95%*BC CI* = –4.33, –0.28), and depressive symptoms (B = –2.22, 95%*BC CI* = –5.09, –0.25; B = –1.94, 95%*BC CI* = –4.10, –0.35). Social cohesion was positively associated with sleep duration, mediated through PA, lifetime discrimination, and perceived stress. Similar patterns were demonstrated for binary outcomes. Yet, effect sizes were relatively small. PNSE was neither directly nor indirectly associated with sleep outcomes by everyday discrimination.

Conclusions: Each PNSE factor was associated with sleep outcomes, mediated by PA and psychosocial stressors. Further research should emphasize effective community efforts to decrease adverse neighborhood conditions and psychosocial factors and increase PA; thereby reducing CVD events for African Americans.

Key words: self-reported sleep; perceived discrimination; mediation analysis; neighborhood social environment; African American; Jackson Heart Study

Statement of Significance

Perceived neighborhood social environment (PNSE) disproportionately impacts sleep outcomes among African Americans. Despite this, little is known about the mechanisms by which behavioral and psychosocial factors mediate such associations. This study may be the first investigation of associations between PNSE and self-reported sleep duration and quality, mediated by physical activity (PA) and psychosocial stressors in a large community-based cohort. Results indicated that associations between PNSE and sleep outcomes might be mediated by PA and psychosocial stressors, shedding new light on the neighborhood-level social determinants of sleep in the Jackson Heart Study participants. Further research is needed using other established prospective large cohort studies to elucidate mechanisms by which PNSE longitudinally impacts sleep outcomes among African Americans adults.

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Introduction

It has been well-documented that both insufficient sleep and long sleep have harmful effects on health, including an increased risk for coronary heart disease [1, 2], stroke [1, 2], diabetes [1, 2], obesity [3], and hypertension [3]. The National Sleep Foundation recommends that US adults sleep between 7 and 9 hours/night [4]. However, the 2005–2008 National Health and Nutrition Examination Survey (NHANES) data indicated that approximately 37% of US adults (aged ≥ 20) reported <7 hours of sleep in a 24-hour period [5]. Furthermore, short sleep duration (<7 hours per night) was more prevalent among African Americans (35%), compared to White Americans (28%) [6]. There is a growing need to elucidate the disparities in sleep health and determinants of sleep among African Americans.

The social determinants [7] of sleep continue to be investigated [8], and increasing research recognizes the key role of neighborhood social environment (e.g. violence, cohesion) [9–14] in relation to sleep disparities [15–17]. For instance, one recent study using the Jackson Heart Study (JHS) demonstrated that higher neighborhood violence and problems were related to shorter sleep duration and poor sleep quality [17]. Studies using data from the MESA found that more unfavorable social environment factors (i.e. high disorder, low safety, and social cohesion) were linked to shorter sleep duration assessed subjectively [15] and objectively [18]. Furthermore, another study indicated that higher Street Smart Walk Score (as a measure of neighborhood walkability) was associated with shorter sleep duration (defined as ≤6 hours/night) particularly among African Americans, thus underscoring the importance of the neighborhood environment to the sleep of African Americans.

Given the racial disparity in sleep [19], focusing on determinants of poor sleep among African Americans and the mechanisms by which neighborhood characteristics are associated with sleep are highly needed. For example, one JHS study investigated the role of perceived stress in relation to sleep and demonstrated that individuals who reported higher perceived stress had shorter sleep duration and lower sleep quality [20]. While another study demonstrated that higher neighborhood violence was linked to shorter sleep duration in JHS participants [17], the other study indicated that higher social cohesion was related to longer sleep duration in MESA participants [18]. However, only one study has investigated a potential mediating role of perceived distress on the associations between neighborhood factors and sleep quality, exclusively for 873 African Americans from Pittsburgh, Pennsylvania [21]. The authors demonstrated that psychological distress partially mediated associations between neighborhood social cohesion and sleep quality [21]. Little is known about the mechanism by which PA and other psychosocial factors (i.e. discrimination, perceived stress, and depression) may mediate associations between neighborhood social environment and sleep duration and quality among African Americans.

Therefore, the purpose of this study was to test PA and psychosocial stressors (i.e. perceived stress, discrimination, and depressive symptoms) as mediators of the associations of PNSE (violence, problems, and social cohesion) with sleep duration and quality among African American adults from the JHS. We tested the hypothesis that the associations of neighborhood social environment with sleep quality and duration were mediated by PA and psychosocial stressors (Figure 1).

Methods

Study design and participants

For this cross-sectional mediation analysis, the baseline data (2000–2004) came from the JHS, a single-site, prospective, community-based cohort study of African-American adults. The study cohort is comprised of 5301 individuals from the tri-county area (Hinds, Madison, and Rankin) of Jackson, Mississippi. Briefly, the goal of the JHS was to study genetic and environmental risk factors for cardiovascular disease (CVD) among African Americans, as described in detail previously [22–24]. In the present study, of the 5301 participants, 57 were excluded from the analysis due to lack of sleep measures (i.e. duration and quality). Additionally, 333 were removed due to missing data on education, alcohol use, smoking status, body mass index (BMI), and total PA. Participants missing data on lifetime and everyday discrimination as well as perceived stress were also removed (n = 198). Eight individuals did not report responses for neighborhood violence, resulting in the total analytic sample of 4705 (3048 for subset with depressive symptoms as a mediator for sleep duration and sleep quality outcomes). The overall analytic samples of binary short (vs recommended [referent]) and long (vs recommended [referent]) sleep outcomes resulted in 4454 (2886 for subset with depressive symptoms as a mediator) and 2162 (1411 for subset with depressive symptoms as a mediator), respectively. The NIH Office of Human Subjects Research Protections approved our study. The study was approved by the institutional review boards of the University of Mississippi Medical Center, Jackson State University, and Tougaloo College. All participants provided informed consent.

Sleep duration and quality measures

Self-reported sleep duration and quality were collected at exam 1 (2000–2004). Sleep duration and quality were measured using the following two items, "During the past month, excluding naps, how many hours of actual sleep did you get at night (or day, if you work at night) on average?" [17, 20] and "During the past month how would you rate your sleep quality overall?" [17, 20] with five responses "1 = excellent", "2 = very good", "3 = good", "4 = fair", and "5 = poor". Using these items, sleep outcomes were created: 1) sleep duration (continuous; hours/night; transformed into minutes per sleep period); 2) a binary short sleep (short≤ 6 hours versus recommended [7–8 hours]; 3) a binary long sleep (long ≥ 9 hours versus recommended [7–8 hours]); and 4) a binary sleep

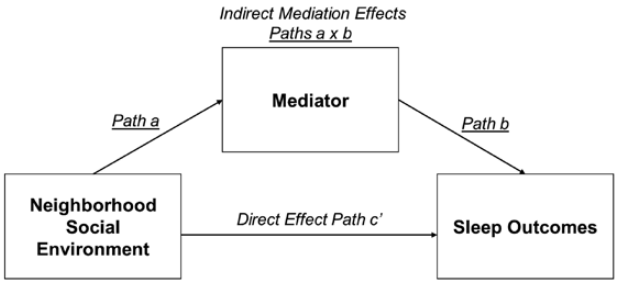

Figure 1. Conceptual model of indirect (a x b) and direct (c') relationships between neighborhood social environment and sleep outcomes among the Jackson Heart Study participants.

Note: Each neighborhood social environment variable (violence, problems, or social cohesion) was investigated separately. Mediators included physical activity, lifetime discrimination, daily discrimination, perceived stress, or depressive symptoms. Outcomes included sleep duration (continuous), binary sleep quality (high vs. low), binary short sleep (≤ 6 h vs. 7-8 h [recommended: referent]), or binary long sleep (≥ 9 hours vs. 7-8 h [recommended: referent]). All analyses controlled for covariates.

quality (high [excellent, very good, good]) versus low [fair, poor]) [25, 26]. Consistent with the previous JHS studies for the classification of the sleep duration [17, 27, 28] most studies found that < 6 hours of sleep was related to overall CVD incidence, compared to 7–8 hours of sleep as a referent [27], whereas other studies found that ≥ 9 hours of sleep was linked to poor general health and high risk for disease [27].

Perceived neighborhood social environment factors

To identify underlying neighborhood constructs, principal component analysis with Promax oblique rotation was used [29, 30]. Three distinct perceived neighborhood social environment (PNSE) factors were identified and assessed as predictors: 1) neighborhood violence, 2) neighborhood problems, and 3) neighborhood social cohesion. The survey questionnaire measuring neighborhood violence included five items on occurrence of 1) neighborhood fights with a weapon, 2) gang fights, 3) sexual assaults/rape, 4) violent arguments, and 5) robbery. The score ranged between 1 (never) and 4 (often). Neighborhood problems included six survey items on 1) neighborhood noise, 2) lack of access to food stores/shopping, 3) lack of adequate access to parks/playgrounds, 4) trash/litter, 5) heavy traffic/speeding cars, and 6) no sidewalks/poorly maintained sidewalks, with a score ranging from 1 (not really a problem) to 4 (very serious problem). Neighborhood social cohesion consisted of four items regarding 1) trust in neighbors, 2) willingness to help neighbors, 3) shared values with neighbors, and 4) extent to which neighbors do not get along, with a score ranging from 1 (strongly disagree) to 4 (strongly agree). Higher scores for neighborhood violence and problems indicate more unfavorable neighborhood perceptions. In contrast, higher scores for neighborhood social cohesion indicate more favorable neighborhood perception. The three PNSE variables had relatively high internal consistencies, with Cronbach's alpha 0.80, 0.76, and 0.77 for neighborhood violence, problems, and social cohesion, respectively.

Unconditional empirical Bayes estimation was used to control for differences with regard to neighborhood social environment factors based on for age and sex of the JHS participants. These estimates were adjusted to the overall distributions of age and sex of the sample. Thus, systematic variations due to age or gender (which could vary in their distribution across census tracts) do not impact these estimates. To improve estimates for census tracts with fewer participants, the participants' responses of each predictor were aggregated to the census tract level [29]. Overall, nineteen participants (median) resided in each tract in the total of 112 census tracts [30].

Mediators—physical activity and psychosocial stressors

Using the JHS Physical Activity Form (JPAC), a total PA score was created based on three types of activity, including active living, sports/exercise, and home activities. The JPAC evaluated PA over the previous 12 months and used 5-level categorical Likert-style response options ranging from 1 (low) to 5 (high). Total PA was calculated by adding the 3 indices (active living [e.g. walking/biking for active transportation and leisure time], sports [exercising and playing sports], and home/yard [gardening, cleaning activities]) with a range of 3–15 for the respondents with complete data. The JPAC was tested against validated waist-worn accelerometer data [31, 32] and was adapted from the Baecke PA questionnaire from the Atherosclerosis Risk in Communities Study. The total PA score was treated as a continuous mediator. To investigate the effects of each PA component, sensitivity analyses were performed.

Using the JHS Discrimination Instrument (JHSDIS) administered by trained African American interviewers, two perceived discrimination variables were tested as mediators: 1) lifetime discrimination (range: 0–9), and 2) everyday discrimination (range: 1–7). Lifetime discrimination was evaluated using the Krieger [33] and Sidney [34] scales with a high internal consistency ($\alpha = 0.78$) [35]. Participants were asked about the instances of mistreatment over the lifetime (yes/no) across 9 domains such as: at school, getting a job, at work, getting medical care, getting housing, on street or in a public setting, from the police or in the courts. These scores were summed to create a continuous lifetime discrimination mediator (range: 0–9).

Williams scale [36] was utilized to create everyday discrimination score, which indicated a high internal consistency of $\alpha = 0.88$ [35]. Participants reported on 9 items; for example, "How often on a day-to-day basis do you have the following experiences?", or "You are treated with less courtesy." or "You are threatened or harassed.", etc. The score for the frequency of everyday discrimination was based on the mean of 9 items between 1 (never) and 7 (several times a day).

Chronic perceived stress scale was assessed with the Global Perceived Stress Scale (GPSS), which was adapted from the standardized stress scales, including Survey of Recent Life Experiences [37], Perceived Stress Scale [38], and Life Events Scale [39]. The GPSS's 8 items were used to evaluate the severity of chronic perceived stress in the past 12 months for 8 domains, such as employment, racism and discrimination, and meeting basic needs, etc. The severity of each domain was rated by participants with a 4-point scale ranging from 0 "not stressful" to 3 "very stressful" with a total range from 0 to 24 (Cronbach α, 0.72) [20].

A continuous depressive symptoms score was tested as a mediator using the 20-items of the Center for Epidemiologic Studies Depression (CES-D) scale (range 0–60) [40]. Participants responded to the frequency of their experiences in various emotional states throughout the previous week, resulting in a score from 0 to 3 for each of the 20 questions. Higher levels of depressive symptoms were defined by a CES-D score of ≥ 16 (i.e. clinically significant depressive symptoms, CES-D score <16, and not reported, the CES-D score was also used as a covariate when it was not used as a mediator). This measure had high internal reliability in the JHS ($\alpha = 0.82$) [41]. One item on restless sleep of the 20 CES-D items was removed because it would influence the sleep outcomes. All analyses were performed based on 19 CES-D items, with a range of 0–57. Four measures (lifetime discrimination, everyday discrimination, perceived stress, and depressive symptoms) were transformed into the standard deviation (SD) from the mean (i.e. a one-SD unit increase) to ease the interpretation [42, 43]. Scoring and definitions of these mediators were consistent with previous JHS studies [9, 20, 42].

Covariates

Potential confounders that may be associated with both predictors and outcomes included demographics, such as age in years, sex (male/female), education attainment (high/low), household income (<$50,000, ≥$50,000, or not reported), and behavioral characteristics (i.e. alcohol consumption in the past 12 months [yes/no], smoking status [never, past, current]) [9]. Health-related factors serving as potential confounders included BMI (kg/m^2), history of medical condition [i.e. yes/no on heart attacks, cancers, stroke, diabetes, or hypertension]) [9]. To account for neighborhood

walkability, objectively measured built environment (i.e. population density based on people/km^2 [2] with 1 mile around participant's residence) was controlled as a confounder [9].

Statistical analysis

All study variables including sleep outcomes, neighborhood social environment variables, mediators, and covariates were summarized, and stratified by sleep duration based on short (≤6 h), recommended (7–8 h) or long sleep duration (≥9 h) and by each neighborhood social environment based on median value (high/low).

The main objective of this study was to examine direct (path c') and indirect (paths a × b) associations between each PNSE and sleep outcomes. Indirect associations (i.e. mediation analyses) included concurrent examinations of the associations between each PNSE and a mediator (considered as an outcome for path a), and associations between a mediator (considered as an exposure variable; path b) and sleep outcomes. All the paths a, b, c (total effect, excluding a mediator as a covariate), c' (direct effect, including a mediator as a covariate), and a × b were adjusted for all covariates.

To test the study hypothesis, multivariable linear regression models [44] were employed using each perceived neighborhood social environment variable one at a time (i.e. neighborhood violence, problems, and social cohesion) as the primary independent variables. Variables for PA, lifetime and everyday discrimination, perceived stress, and depressive symptoms variables were each tested as mediators separately, with sleep duration and sleep quality as the outcomes. Results of three binary outcomes (sleep quality, short sleep, and long sleep) were expressed as odds ratios (OR, based on an exponent of a log-odds estimate). Significance of an OR was expressed by not including 1.0 between 95% confidence intervals.

Using bootstrap resampling approach (k = 5000) with 95% bias-corrected confidence intervals (BC CIs) of the indirect effects [44], a role of mediation (i.e. PA, lifetime and everyday discrimination, perceived stress, and depressive symptoms) was tested by using the PROCESS Macro version 3.4 for SAS 9.4 (SAS, Cary, NC) [44]. The PROCESS macro offers an inferential statistical examination for indirect mediation effects of exposure variables on the outcome via the mediators, contributing to a decrease in type 1 errors. This macro yields greater statistical power than conventional causal approach for mediation tests. Additionally, it does not necessitate a normal sampling distribution [44, 45]. Assessment of statistically significant mediation was determined by a BC CI, without zero for a continuous outcome [44].

As the missingness for depressive symptoms was quite high, and population with depressive symptoms may differ by sociodemographic characteristics and other factors, we imputed 10 complete datasets for depressive symptoms, total PA, lifetime discrimination, and everyday discrimination (1889, 269, 202, and 117 were missing, respectively). To perform the multiple imputation model (SAS Proc MI) for the missingness, we included age, BMI, lifetime discrimination, everyday discrimination, perceived stress, and population density. Based on the imputation process, the total analytic sample resulted in 5155 for sleep duration and quality outcomes, 4871 for short sleep outcome, and 2360 for long sleep outcome. These samples were used for sensitivity analyses (**data not shown**).

Results

All the variables used in the analyses are summarized in Table 1. Mean age of the participants was 55.0 years (±12.8) and participants were predominantly female (63%). Most of them graduated from at least high school (80%). Roughly 30% earned $50,000/year or greater. On average, participants slept 6.4 hours/night, had a BMI of 31.8 kg/m^2 (±7.29), and had a total PA score of 6.5 (±1.5). Nearly 70% of the participants reported never smoking, and about 45% reported alcohol use in the past 12 months. Over 60% had a history of chronic diseases.

Participants who reported short sleep ≤ 6 hours/night were younger, had a higher education attainment and income ≥ $50,000, had a higher BMI, engaged in a lower total PA than the recommended sleep duration group but higher than the long sleep duration group, were more likely to be current smokers and to drink alcohol in the past 12 months, and had history of previous chronic diseases. Those with short sleep duration reported higher lifetime discrimination, everyday discrimination, perceived stress, and relatively higher depressive symptoms compared to other sleep duration groups (all *p-values* <.05) (Table 1). Those who reported lower sleep quality were younger, tended to be female, had a lower education attainment and income ≥ $50,000, had a higher BMI, engaged in lower total PA, were more likely to be current smokers, and had a higher likelihood of previous chronic diseases compared to those with high sleep quality. Those with low sleep quality reported higher lifetime discrimination, everyday discrimination, perceived stress, relatively higher depressive symptoms, and higher neighborhood violence and problems, and lower neighborhood social cohesion compared to high sleep quality group (all *p-values* <.05; Table 1).

Those who reported higher neighborhood violence tended to be older, be female, have less than a high school diploma, have a lower income, have a higher BMI, engage in lower total PA, be current smokers, be less likely to drink alcohol, and have a history of previous chronic diseases, compared to those reported lower neighborhood violence (all $p < .05$; Table 2). The patterns of socio-demographics, health-related factors, and psychosocial factors for those who reported high neighborhood violence appeared to be similar to those who reported high neighborhood problems and low neighborhood social cohesion.

Total PA as a mediator on associations between PNSE and sleep outcomes

Neighborhood violence, problems, and social cohesion were significantly indirectly associated with sleep duration (minutes/night) via total PA (β [Paths ab] = −1.97, 95% *BC CI* = −3.76, −0.60; β = −1.23, 95% *BC CI* = −2.55, −0.27, and β = 1.42, 95% *BC CI* = 0.18, 2.95, respectively) (Table 3). Higher neighborhood violence and problems were significantly associated with lower total PA (Path a: violence: β = −0.82, *SE* = 0.26, 95% *CI* = −1.32, −0.31, $p < .01$; problems: β = −0.50, *SE* = 0.19, 95% *CI* = −0.87, −0.14, $p < .01$, respectively) and higher social cohesion was associated with higher total PA (social cohesion: β = 0.58, *SE* = 0.25, 95% *CI* = 0.09, 1.07, $p < .05$). In turn, higher total PA was significantly associated with longer sleep duration (Path b: Violence: β = 2.41, *SE* = 0.69, 95% *CI* = 1.06, 3.75; Problems: β = 2.43, *SE* = 0.69, 95% *CI* = 1.08, 3.78; and social cohesion: β = 2.44, *SE* = 0.69, 95% *CI* = 1.09, 3.78, all $p < .001$). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Similar patterns of associations for each path were demonstrated for the binary sleep quality outcome (Table 4). Associations between each PNSE and sleep quality were significantly mediated by total PA.

Neighborhood violence, problems, and social cohesion were significantly indirectly associated with short sleep duration (vs recommended) via total PA (OR [Paths ab] = 1.06, 95% *BC CI* = 1.02, 1.12; OR = 1.04, 95% *BC CI* = 1.01, 1.07, and OR = 0.95, 95% *BC CI* = 0.91, 0.99, respectively) (Table 5). Higher neighborhood violence

Table 1. Demographic characteristics, health-related factors, psychosocial factors, and census-tract level variables (n = 4705)

	Overall, n (%)	Short (≤ 6 hours) n = 2543 (%)	Recommended (7–8 hours) n =1911 (%)	Long (≥ 9 hours) n = 251 (%)	*Pc*	High sleep quality, n = 3087 (%)	Low sleep quality, n = 1618 (%)	*Pc*
Demographic characteristics								
Age (years), *M* (±SD)	55.04 (±12.82)	54.15 (±12.46)	55.64 (±12.97)	59.54 (14.07)	**<.0001**	55.71 (±12.77)	53.77 (±12.81)	**<.0001**
Female	2983 (63.40)	1577 (62.01)	1235 (64.63)	171 (68.13)	0.0561	1904 (61.68)	1079 (66.69)	**0.0007**
Education					**<.0001**			**0.0087**
High school graduate or more	3769 (80.11)	2066 (81.24)	1530 (80.06)	173 (68.92)		2507 (81.21)	1262 (78.00)	
Less than high school	936 (19.89)	477 (18.76)	381 (19.94)	78 (31.08)		580 (18.79)	356 (22.00)	
Income					**0.0001**			**<.0001**
≥$50,000	1391 (29.56)	777 (30.55)	571 (29.88)	43 (17.13)		1005 (32.56)	386 (23.86)	
<$50,000	2608 (55.43)	1382 (54.35)	1053 (55.10)	173 (68.92)		1626 (52.67)	982 (60.69)	
Not reported	706 (15.01)	384 (15.10)	287 (15.02)	35 (13.94)		456 (14.77)	250 (15.45)	
Health-related factors								
Sleep duration in hours, *M* (±SD)	6.43 (±1.50)	5.33 (±0.88)	7.47 (±0.50)	9.71 (1.16)	**<.0001**	6.89 (±1.31)	5.56 (±1.46)	**<.0001**
Body Mass Index, *M* (±SD)	31.78 (±7.29)	32.05 (±7.42)	31.52 (±7.17)	31.11 (6.74)	**0.019**	31.34 (±7.01)	32.63 (±7.72)	**<.0001**
Total physical activity, *M* (±SD)	6.53 (±1.99)	6.48 (±1.97)	6.64 (±2.00)	6.23 (2.00)	**0.0011**	6.63 (±2.02)	6.33 (±1.92)	**<.0001**
Smoking status					**0.0291**			**0.0028**
Never	3221 (68.46)	1733 (68.15)	1337 (69.96)	151 (60.16)		2151 (69.68)	1070 (66.13)	
Past	886 (18.83)	491 (19.31)	337 (17.63)	58 (23.11)		580 (18.79)	306 (18.91)	
Current	598 (12.71)	319 (12.54)	237 (12.40)	42 (16.73)		356 (11.53)	242 (14.96)	
Drinking alcohol in the past 12 months	2163 (45.97)	1212 (47.66)	869 (45.57)	82 (32.67)	**<.0001**	1395 (45.19)	768 (47.47)	0.1367
History of previous chronic diseases	2891 (61.45)	1555 (61.15)	1160 (60.70)	176 (70.12)	**0.0142**	1849 (59.90)	1042 (64.40)	**0.0026**
Psychosocial factors								
Lifetime discrimination, *M* (±SD)	2.96 (±2.13)	3.18 (±2.14)	2.79 (±2.09)	2.08 (1.91)	**<.0001**	2.81 (±2.09)	3.24 (±2.17)	**<.0001**
Everyday discrimination, *M* (±SD)	2.08 (±1.02)	2.17 (±1.05)	2.00 (±0.96)	1.84 (1.00)	**<.0001**	1.99 (±0.95)	2.26 (±1.11)	**<.0001**
Perceived stress, *M* (±SD)	5.15 (±4.39)	5.66 (±4.53)	4.63 (±4.13)	3.95 (4.06)	**<.0001**	4.40 (±3.97)	6.58 (±4.78)	**<.0001**
Depressive symptoms								
High (CES-D≥16)	606 (12.88)	370 (14.55)	196 (10.26)	40 (15.94)	**<.0001**	276 (8.94)	330 (20.40)	**<.0001**
Low (CES-D<16)	2442 (51.90)	1267 (49.82)	1053 (55.10)	122 (48.61)		1739 (56.33)	703 (43.45)	
Not reported	1657 (35.22)	906 (35.63)	662 (34.64)	89 (35.46)		1072 (34.73)	585 (36.16)	
Census-tract level variables, *M* (±SD)								
Perceived neighborhood social environment[a]								
Violence	1.26 (±0.13)	1.26 (±0.13)	1.26 (±0.13)	1.28 (0.12)	0.1366	1.26 (±0.12)	1.27 (±0.13)	**0.0182**
Problems	1.56 (±0.19)	1.56 (±0.19)	1.56 (±0.19)	1.59 (0.17)	0.0539	1.56 (±0.19)	1.57 (±0.19)	**0.0192**
Social cohesion	3.01 (±0.12)	3.01 (0.12)	3.01 (±0.12)	3.00 (0.12)	0.3997	3.01 (±0.12)	3.00 (±0.12)	**0.0038**
Objectively measured population density[b]	816.59 (±489.52)	812.49 (±487.77)	818.39 (±488.27)	844.38 (516.90)	0.6027	806.63 (±487.96)	835.60 (±492.06)	0.0538

Note: M: Mean. SD: Standard Deviation. CES-D: Center for Epidemiologic Studies Depression.
[a]Each perceived social environment variable was based on unconditional empirical Bayes estimation adjusting for age and sex.
[b]Population density was measured around 1 mile from participant's residence.
[c]P-values were based on t-tests for continuous variables and chi-square tests for categorical variables. For three categorical sleep duration, the ANOVA test was used for continuous variables. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

Table 2. Demographic characteristics, health-related factors, psychosocial factors, and census-tract level variables based on neighborhood social environment factors (n = 4705)

	Neighborhood violence			Neighborhood problems			Neighborhood social cohesion		
	High n =2363	Low n = 2342	Pc	High n = 2358	Low n = 2347	Pc	High n = 2355	Low n = 2350	Pc
Demographic characteristics									
Age (years), M (±SD)	57.71 (±12.83)	52.35 (±12.23)	**<.0001**	57.19 (±12.76)	52.89 (±12.51)	**<.0001**	54.25 (±12.48)	55.84 (±13.10)	**<.0001**
Female	1541 (65.21)	1442 (61.57)	**0.0095**	1535 (65.10)	1448 (61.70)	**0.0154**	1468 (62.34)	1515 (64.47)	0.1289
Education			**<.0001**			**<.0001**			**<.0001**
High school graduate or more	1714 (72.53)	2055 (87.75)		1715 (72.73)	2054 (87.52)		2003 (85.05)	1766 (75.15)	
Less than high school	649 (27.47)	287 (12.25)		643 (27.27)	293 (12.48)		352 (14.95)	584 (24.85)	
Income			**<.0001**			**<.0001**			**<.0001**
≥$50,000	442 (18.71)	949 (40.52)		430 (18.24)	961 (40.95)		907 (38.51)	484 (20.60)	
<$50,000	1585 (67.08)	1023 (43.68)		1581 (67.05)	1027 (43.76)		1098 (46.62)	1510 (64.26)	
Not reported	336 (14.22)	370 (15.80)		347 (14.72)	359 (15.30)		350 (14.86)	356 (15.15)	
Health-related factors									
Sleep duration in hours, M (±SD)	6.45 (±1.61)	6.42 (±1.39)	0.5422	6.42 (±1.57)	6.45 (±1.44)	0.6226	6.46 (±1.46)	6.41 (±1.55)	0.2536
Body Mass Index, M (±SD)	32.04 (±7.44)	31.52 (±7.12)	**0.0148**	31.91 (±7.37)	31.65 (±7.20)	0.2261	31.50 (±7.09)	32.06 (±7.47)	**0.0087**
Total physical activity, M (±SD)	6.25 (±1.96)	6.81 (±1.98)	**<.0001**	6.28 (±1.97)	6.78 (±1.98)	**<.0001**	6.73 (±2.00)	6.32 (±1.95)	**<.0001**
Smoking status			**<.0001**			**<.0001**			**<.0001**
Never	1525 (64.54)	1696 (72.42)		1528 (64.80)	1693 (72.13)		1694 (71.93)	1527 (64.98)	
Past	487 (20.61)	399 (17.04)		484 (20.53)	402 (17.13)		402 (17.11)	483 (20.55)	
Current	351 (14.85)	247 (10.55)		346 (14.67)	252 (10.74)		258 (10.96)	340 (14.47)	
Drinking alcohol in the past 12 months	975 (41.26)	1188 (50.73)	**<.0001**	993 (42.11)	1170 (49.85)	**<.0001**	1148 (48.75)	1015 (43.19)	**0.0001**
History of previous chronic diseases	1611 (68.18)	1280 (54.65)	**<.0001**	1587 (67.30)	1304 (55.56)	**<.0001**	1350 (57.32)	1541 (65.57)	**<.0001**
Psychosocial factors									
Lifetime discrimination, M (±SD)	2.76 (±2.10)	3.17 (±2.14)	**<.0001**	2.77 (±2.11)	3.15 (±2.12)	**<.0001**	3.07 (±2.11)	2.85 (±2.14)	**0.0004**
Daily discrimination, M (±SD)	2.04 (±1.04)	2.13 (±0.99)	**0.0051**	2.07 (±1.05)	2.10 (±0.98)	0.3005	2.08 (±0.97)	2.08 (±1.06)	0.9391
Perceived stress, M (±SD)	5.19 (±4.60)	5.12 (±4.16)	0.5998	5.15 (±4.57)	5.15 (±4.19)	0.9965	4.97 (±4.18)	5.33 (±4.58)	**0.0043**
Depressive symptoms, M (±SD)									
High (CES-D≥16)	338 (14.30)	268 (11.44)	**<.0001**	338 (14.33)	268 (11.42)	**<.0001**	272 (11.55)	334 (14.21)	**<.0001**
Low (CES-D<16)	1128 (47.74)	1314 (56.11)		1101 (46.69)	1341 (57.14)		1321 (56.09)	1121 (47.70)	
Not reported	897 (37.96)	760 (32.45)		919 (38.97)	738 (31.44)		762 (32.36)	895 (38.09)	
Census-tract level variables, M (±SD)									
Perceived neighborhood social environment[a]									
Violence	1.36 (±0.09)	1.16 (±0.06)	**<.0001**	1.35 (±0.10)	1.17 (±0.07)	**<.0001**	1.19 (±0.07)	1.34 (±0.12)	**<.0001**
Problems	1.71 (±0.12)	1.41 (±0.10)	**<.0001**	1.72 (±0.11)	1.41 (±0.10)	**<.0001**	1.45 (±0.13)	1.68 (±0.16)	**<.0001**
Social cohesion	2.94 (±0.12)	3.08 (±0.08)	**<.0001**	2.92 (±0.09)	3.10 (±0.08)	**<.0001**	3.11 (±0.06)	2.91 (±0.09)	**<.0001**
Objectively measured population density[b]	1082.78 (372.91)	548.02 (±444.42)	**<.0001**	1086.74 (386.57)	545.17 (±428.12)	**<.0001**	634.01 (±482.82)	999.56 (423.49)	**<.0001**

Note: M: Mean. SD: Standard Deviation. CES-D: Center for Epidemiologic Studies Depression.
[a]Each perceived social environment variable was based on unconditional empirical Bayes estimation adjusting for age and sex.
[b]Population density was measured around 1 mile from participant's residence.
[c]P-values were based on t-tests for continuous variables and chi-square tests for categorical variables. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

Table 3. Indirect and direct associations between neighborhood social environment (**IV**) and sleep duration in minutes (**DV**) via mediators (**M**) (N=4,705)

	Effect of IV on M (path a)			Effect of M on DV (path b)			Total Effect (path c)			Direct Effect (path c')			Indirect Effect (paths a x b)		
	beta	SE	95% CI	beta	SE	95% CI	beta	SE	95% CI	beta	SE	95% CI	beta	SE	95% BC CI
Via Total PA (M)															
Violence	-0.82**	0.26	-1.32, -0.31	2.41***	0.69	1.06, 3.75	-5.12	12.09	-28.82, 18.59	-3.15	12.09	-26.85, 20.55	-1.97****	0.82	-3.76, -0.60
Problems	-0.50**	0.19	-0.87, -0.14	2.43***	0.69	1.08, 3.78	3.17	8.74	-13.96, 20.29	4.39	8.73	-12.73, 21.51	-1.23****	0.58	-2.55, -0.27
Social cohesion	0.58*	0.25	0.09, 1.07	2.44***	0.69	1.09, 3.78	-9.23	11.77	-32.31, 13.84	-10.65	11.76	-33.71, 12.41	1.42****	0.72	0.18, 2.95
Via Lifetime Discrimination (M)															
Violence	-0.41***	0.12	-0.64, -0.18	-6.33***	1.51	-9.30, -3.37	-0.54	12.10	-24.25, 23.17	-3.15	12.09	-26.85, 20.55	2.61****	1.00	0.93, 4.80
Problems	-0.36***	0.08	-0.52, -0.20	-6.27***	1.51	-9.24, -3.30	6.65	8.73	-10.47, 23.76	4.39	8.73	-12.73, 21.51	2.25****	0.77	0.93, 3.94
Social cohesion	0.30**	0.11	0.08, 0.52	-6.26***	1.51	-9.23, -3.30	-12.53	11.77	-35.61, 10.55	-10.65	11.76	-33.71, 12.41	-1.87****	0.86	-3.86, -0.42
Via Everyday Discrimination (M)															
Violence	0.01	0.12	-0.21, 0.24	-2.26	1.52	-5.24, 0.72	-3.18	12.09	-26.89, 20.52	-3.15	12.09	-26.85, 20.55	-0.03	0.31	-0.69, 0.60
Problems	0.10	0.08	-0.07, 0.26	-2.27	1.52	-5.25, 0.71	4.17	8.73	-12.95, 21.28	4.39	8.73	-12.73, 21.51	-0.23	0.27	-0.91, 0.17
Social cohesion	-0.15	0.11	-0.37, 0.07	-2.28	1.52	-5.26, 0.70	-10.30	11.76	-33.36, 12.75	-10.65	11.76	-33.71, 12.41	0.35	0.40	-0.24, 1.37
Via Perceived Stress (M)															
Violence	0.27*	0.12	0.04, 0.50	-11.42***	1.52	-14.40, -8.44	-6.23	12.15	-30.06, 17.59	-3.15	12.09	-26.85, 20.55	-3.08****	1.46	-6.20, -0.41
Problems	0.19*	0.08	0.02, 0.35	-11.46***	1.52	-14.44, -8.48	2.23	8.78	-14.98, 19.44	4.39	8.73	-12.73, 21.51	-2.17****	1.03	-4.33, -0.28
Social cohesion	-0.23*	0.11	-0.45, -0.01	-11.47***	1.52	-14.45, -8.49	-8.05	11.83	-31.23, 15.14	-10.65	11.76	-33.71, 12.41	2.61	1.37	-0.04, 5.43
Via Depressive Symptoms (M)[a]															
Violence	0.44**	0.16	0.13, 0.75	-5.01**	1.76	-8.47, -1.55	2.48	15.25	-27.42, 32.39	4.70	15.25	-25.21, 34.61	-2.22****	1.24	-5.09, -0.25
Problems	0.38***	0.11	0.16, 0.60	-5.11**	1.76	-8.57, -1.65	10.19	10.81	-11.01, 31.40	12.14	10.82	-9.08, 33.36	-1.94****	0.96	-4.10, -0.35
Social cohesion	-0.20	0.15	-0.50, 0.09	-5.03**	1.76	-8.48, -1.58	-14.50	14.69	-43.30, 14.30	-15.53	14.68	-44.30, 13.25	1.03	0.93	-0.54, 3.10

Note: *P*-values: *$p < .05$; **$p < .01$; ***$p < .001$; **** indicates 95% *BC CI* is statistically significant with a probability of 95%.
[a]Sample size for depressive symptoms (M) = 3048. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

Table 4. Indirect and direct associations between neighborhood social environment (IV) and sleep quality (DV) via mediators (M) (*N* = 4705)

	Effect of IV on M (path a)			Effect of M on DV (path b)		Direct Effect (path c')		Indirect Effect (paths a x b)	
	beta	SE	95% CI	OR	95% CI	OR	95% CI	OR	95% BC CI
Via Total PA (M)									
Violence	−0.82**	0.26	−1.32, −0.31	1.10***	1.06, 1.14	1.04	0.58, 1.87	0.93****	0.87, 0.97
Problems	−0.50**	0.19	−0.87, −0.14	1.10***	1.06, 1.14	1.04	0.68, 1.59	0.95****	0.92, 0.99
Social cohesion	0.58*	0.25	0.09, 1.07	1.10***	1.06, 1.14	0.96	0.54, 1.71	1.06****	1.01, 1.11
Via Lifetime Discrimination (M)									
Violence	−0.41***	0.12	−0.64, −0.18	0.91*	0.85, 0.98	1.04	0.58, 1.87	1.04****	1.00, 1.08
Problems	−0.36***	0.08	−0.52, −0.20	0.91*	0.85, 0.98	1.04	0.68, 1.59	1.03****	1.01, 1.07
Social cohesion	0.30**	0.11	0.08, 0.52	0.91*	0.85, 0.98	0.96	0.54, 1.71	0.97****	0.94, 1.00
Via Everyday Discrimination (M)									
Violence	0.01	0.12	−0.21, 0.24	0.95	0.88, 1.02	1.04	0.58, 1.87	1.00	0.98, 1.02
Problems	0.10	0.08	−0.07, 0.26	0.95	0.88, 1.02	1.04	0.68, 1.59	0.99	0.98, 1.01
Social cohesion	−0.15	0.11	−0.37, 0.07	0.95	0.88, 1.02	0.96	0.54, 1.71	1.01	1.00, 1.03
Via Perceived Stress (M)									
Violence	0.27*	0.12	0.04, 0.50	0.68***	0.63, 0.73	1.04	0.58, 1.87	0.90****	0.82, 0.99
Problems	0.19*	0.08	0.02, 0.35	0.67***	0.63, 0.73	1.04	0.68, 1.59	0.93****	0.86, 0.99
Social cohesion	−0.23*	0.11	−0.45, −0.01	0.68***	0.63, 0.73	0.96	0.54, 1.71	1.09****	1.00, 1.20
Via Depressive Symptoms (M)[a]									
Violence	0.44**	0.16	0.13, 0.75	0.65***	0.59, 0.71	1.68	0.77, 3.63	0.83****	0.70, 0.95
Problems	0.38***	0.11	0.16, 0.60	0.65***	0.59, 0.71	1.56	0.90, 2.71	0.85****	0.76, 0.94
Social cohesion	−0.20	0.15	−0.50, 0.09	0.65***	0.59, 0.71	0.84	0.40, 1.77	1.09	0.95, 1.26

Note: P-values: *$p < .05$; **$p < .01$; ***$p < .001$; **** indicates 95% *BC CI* is statistically significant with a probability of 95%.
[a]Sample size for depressive symptoms (M) = 3,048. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

and problems were significantly associated with lower total PA (Path a: violence: β = −0.87, *SE* = 0.26, 95% *CI* = −1.38, −0.35; problems: β = −0.52, *SE* = 0.19, 95% *CI* = −0.90, −0.15, respectively) and higher social cohesion was associated with higher total PA (social cohesion: β = 0.68, *SE* = 0.26, 95% *CI* = 0.17, 1.18, all $p < .01$). In turn, higher total PA appeared to be protective effects for short sleep duration (Path b: OR = 0.93, 95% *CI* = 0.91, 0.97, all $p < .01$). None of the PNSE variables were associated with short sleep duration (Path c' [direct effect] and Path c [total effect]). Each PNSE factor was neither directly nor indirectly associated with long sleep duration, mediated through total PA (Table 6).

To further elucidate each PA domain (active living, home/life, and sport indices), sensitivity mediation analyses were performed to investigate associations between each PNSE factor and sleep outcomes and mediated by each PA domain (Supplemental Tables 1-4). Overall, the results indicated that significant indirect mediation was generally driven by active living and sport/exercise activities, but not home/life activities for sleep quality and short sleep outcomes. Mediation of the relationship of PNSE factors with sleep duration (minutes) was driven by sports index, whereas no mediation was found for a long sleep outcome.

Lifetime discrimination as a mediator on associations between PNSE and sleep outcomes

Neighborhood violence, problems, and social cohesion were significantly indirectly associated with sleep duration (minutes/night) via lifetime discrimination (β [Paths ab] = 2.61, 95% *BC CI* = 0.93, 4.80; β = 2.25, 95% *BC CI* = 0.93, 3.94, and β = −1.87, 95% *BC CI* = −3.86, −0.42, respectively) (Table 3). Neighborhood violence and problems were significantly associated with lower lifetime discrimination (Path a [violence]: β = −0.41, *SE* = 0.12, 95% *CI* = −0.64, −0.18; problems: β = −0.36, *SE* = 0.08, 95% *CI* = −0.52, −0.20, both $p < .001$, respectively), while higher social cohesion was related to higher lifetime discrimination (social cohesion: β = 0.30, *SE* = 0.11, 95% *CI* = 0.08, 0.52, $p < .01$). In turn, higher lifetime discrimination was significantly associated with shorter sleep duration (Path b [Violence]: β = −6.33, *SE* = 1.51, 95% *CI* = −9.30, −3.37; Problems: β = −6.27, *SE* = 1.51, 95% *CI* = −9.24, −3.30; and social cohesion: β = −6.26, *SE* = 1.51, 95% *CI* = −9.23, −3.30, all $p < .0001$). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Similar patterns of associations for each path were demonstrated for binary sleep quality and long sleep outcomes (Tables 4 and 6). Associations between each PNSE and both sleep quality and long sleep were significantly mediated by lifetime discrimination.

Neighborhood violence, problems, and social cohesion were significantly indirectly associated with short sleep (versus recommended) via lifetime discrimination (OR [Paths ab] = 0.95, 95% *BC CI* = 0.91, 0.99; OR = 0.96, 95% *BC CI* = 0.93, 0.99, and OR = 1.03, 95% *BC CI* = 1.01, 1.08, respectively) (Table 4). Higher neighborhood violence, problems, and social cohesion were significantly associated with lower lifetime discrimination (Path a [violence]: β = −0.43, *SE* = 0.12, 95% *CI* = −0.66, −0.19; problems: β = −0.36, *SE* = 0.09, 95% *CI* = −0.53, −0.19, both $p < .001$, respectively) and higher lifetime discrimination (social cohesion: β = 0.30, *SE* = 0.12, 95%

Table 5. Indirect and direct associations between neighborhood social environment (**IV**) and short sleep ([≤6h] vs recommended [7-8h]) (**DV**) via mediators (**M**) (N = 4454)

	Effect of IV on M (path a)			Effect of M on DV (path b)		Direct Effect (path c')		Indirect Effect (paths a x b)	
	beta	SE	95% CI	OR	95% CI	OR	95% CI	OR	95% BC CI
Via total PA (M)									
Violence	−0.87**	0.26	−1.38, −0.35	0.93***	0.91, 0.97	1.17	0.66, 2.07	1.06****	1.02, 1.12
Problems	−0.52**	0.19	−0.90, −0.15	0.93***	0.90, 0.96	1.00	0.67, 1.51	1.04****	1.01, 1.07
Social cohesion	0.68**	0.26	0.17, 1.18	0.93***	0.90, 0.96	1.27	0.73, 2.21	0.95****	0.91, 0.99
Via lifetime discrimination (M)									
Violence	−0.43***	0.12	−0.66, −0.19	1.12**	1.04, 1.20	1.17	0.66, 2.07	0.95****	0.91, 0.99
Problems	−0.36***	0.09	−0.53, −0.19	1.12**	1.04, 1.20	1.00	0.67, 1.51	0.96****	0.93, 0.99
Social cohesion	0.30*	0.12	0.07, 0.53	1.12**	1.04, 1.20	1.27	0.73, 2.21	1.03****	1.01, 1.08
Via Everyday Discrimination (M)									
Violence	0.02	0.12	−0.22, 0.25	1.03	0.96, 1.11	1.17	0.66, 2.07	1.00	0.99, 1.01
Problems	0.11	0.09	−0.06, 0.28	1.03	0.96, 1.11	1.00	0.67, 1.51	1.00	0.99, 1.02
Social cohesion	−0.17	0.12	−0.40, 0.06	1.03	0.96, 1.11	1.27	0.73, 2.21	0.99	0.98, 1.01
Via Perceived Stress (M)									
Violence	0.27*	0.12	0.03, 0.50	1.20***	1.11, 1.29	1.17	0.66, 2.07	1.05****	1.00, 1.11
Problems	0.18*	0.09	0.01, 0.35	1.20***	1.11, 1.29	1.00	0.67, 1.51	1.03****	1.00, 1.07
Social cohesion	−0.24*	0.12	−0.47, −0.02	1.20***	1.12, 1.29	1.27	0.73, 2.21	0.96****	0.91, 1.00
Via Depressive Symptoms (M)[a]									
Violence	0.41*	0.16	0.09, 0.73	1.12**	1.03, 1.23	1.19	0.57, 2.47	1.05****	1.00, 1.12
Problems	0.38**	0.11	0.15, 0.60	1.13**	1.03, 1.23	0.94	0.56, 1.57	1.05****	1.01, 1.10
Social cohesion	−0.15	0.16	−0.46, 0.15	1.13**	1.03, 1.23	1.20	0.60, 2.42	0.98	0.93, 1.02

Note: P-values: *p < .05; **p < .01; ***p < .001; **** indicates 95% *BC CI* is statistically significant with a probability of 95%.
[a]Sample size for depressive symptoms (M) = 2886. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

CI = 0.07, 0.53, p < .05). In turn, higher lifetime discrimination was significantly associated with shorter sleep duration (Path b: OR = 1.12, 95% *CI* = 1.04, 1.20, all p < .01). None of the PNSE variables were associated with short sleep duration (Path c' [direct effect] and Path c [total effect]).

Everyday discrimination as a mediator on associations between PNSE and sleep outcomes

When everyday discrimination was examined as a mediator, none of the associations of each PNSE for each path were significantly associated with any sleep outcomes (Tables 3–6).

Perceived stress as a mediator on associations between PNSE and sleep outcomes

Neighborhood violence and problems were significantly indirectly associated with sleep duration (minutes/night) via perceived stress (β [Paths ab] = −3.08, 95% *BC CI* = −6.20, −0.41; and β = −2.17, 95% *BC CI* = −4.33, −0.28, respectively) (Table 3). Higher neighborhood violence and problems were significantly associated with higher perceived stress (Path a [violence]: β = 0.27, *SE* = 0.12, 95% *CI* = 0.04, 0.50; problems: β = 0.19, *SE* = 0.08, 95% *CI* = 0.02, 0.35, both p < .05, respectively), and higher social cohesion was also significantly associated with lower perceived stress (social cohesion: β = −0.23, *SE* = 0.11, 95% *CI* = −0.45, −0.01, p < .05). In turn, higher perceived stress was significantly associated with shorter sleep duration (Path b-Violence: β = −11.42, *SE* = 1.52, 95% *CI* = −14.40, −8.44; Problems: β = −11.46, *SE* = 1.52, 95% *CI* = −14.44, −8.48; and social cohesion: β = −11.47, *SE* = 1.52, 95% *CI* = −14.45, −8.49, all p < .0001). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Similar patterns of associations for each path were shown for binary sleep quality outcome (Table 4). Yet only associations of neighborhood violence and problems (but not social cohesion) and sleep quality were significantly mediated by perceived stress.

Neighborhood violence and problems were significantly indirectly associated with short sleep (versus recommended) via perceived stress (OR [Paths ab] = 1.05, 95% *BC CI* = 1.00, 1.11; OR = 1.03, 95% *BC CI* = 1.00, 1.07) (Table 5). Higher neighborhood violence and problems were significantly associated with higher perceived stress (Path a [violence]: β = 0.27, *SE* = 0.12, 95% *CI* = 0.03, 0.50; problems: β = 0.18, *SE* = 0.09, 95% *CI* = 0.01, 0.35; p < .05), and higher social cohesion was significantly associated with lower perceived stress (social cohesion: β = −0.24, *SE* = 0.12, 95% *CI* = −0.47, −0.02, p < .05). In turn, higher perceived stress was significantly associated with shorter sleep duration (Path b: OR = 1.20, 95% *CI* = 1.11 or 1.12, 1.29, all p < .001). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Each PNSE variable was neither directly nor indirectly associated with long sleep, mediated by perceived stress (Table 6).

Depressive symptoms as a mediator on associations between PNSE and sleep outcomes

Using the subset of the total analytic sample, neighborhood violence and problems were significantly indirectly associated with

Table 6. Indirect and direct associations between neighborhood social environment (**IV**) and long sleep ([≥9h] vs recommended [7-8h]) (**DV**) via mediators (**M**) (*N* = 2162)

	Effect of IV on M (path a)			Effect of M on DV (path b)		Direct Effect (path c')		Indirect Effect (paths a x b)	
	beta	SE	95% CI	OR	95% CI	OR	95% CI	OR	95% BC CI
Via Total PA (M)									
Violence	−0.45	0.38	−1.20, 0.29	0.96	0.89, 1.03	1.08	0.32, 3.69	1.02	0.98, 1.09
Problems	−0.32	0.28	−0.86, −0.22	0.96	0.89, 1.03	1.09	0.43, 2.74	1.01	0.98, 1.07
Social cohesion	0.16	0.37	−0.56, 0.88	0.96	0.89, 1.03	1.06	0.32, 3.50	0.99	0.94, 1.03
Via Lifetime Discrimination (M)									
Violence	−0.52**	0.17	−0.85, −0.19	0.77**	0.64, 0.91	1.08	0.32, 3.69	1.15****	1.03, 1.35
Problems	−0.48***	0.12	−0.72, −0.24	0.77**	0.65, 0.91	1.09	0.43, 2.74	1.14****	1.04, 1.29
Social cohesion	0.45**	0.16	0.13, 0.76	0.76**	0.64, 0.91	1.06	0.32, 3.50	0.89****	0.77, 0.98
Via Everyday Discrimination (M)									
Violence	0.11	0.17	−0.23, 0.44	1.00	0.85, 1.18	1.08	0.32, 3.69	1.00	0.96, 1.04
Problems	0.18	0.12	−0.06, 0.42	1.00	0.85, 1.18	1.09	0.43, 2.74	1.00	0.95, 1.04
Social cohesion	−0.19	0.16	−0.52, 0.13	1.00	0.85, 1.18	1.06	0.32, 3.50	1.00	0.95, 1.06
Via Perceived Stress (M)									
Violence	0.01	0.17	−0.33, 0.35	0.92	0.78, 1.09	1.08	0.32, 3.69	1.00	0.96, 1.04
Problems	0.04	0.13	−0.21, 0.28	0.92	0.78, 1.09	1.09	0.43, 2.74	1.00	0.96, 1.03
Social cohesion	−0.10	0.17	−0.42, 0.23	0.92	0.78, 1.09	1.06	0.32, 3.50	1.01	0.97, 1.06
Via Depressive Symptoms (M)									
Violence	0.65**	0.24	0.18, 1.11	1.34***	1.12, 1.59	1.08	0.22, 5.39	1.21****	1.03, 1.53
Problems	0.51**	0.17	0.18, 0.84	1.33**	1.12, 1.59	1.30	0.40, 4.24	1.16****	1.03, 1.36
Social cohesion	−0.54*	0.22	−0.98, −0.11	1.34***	1.13, 1.59	1.07	0.23, 4.96	0.85****	0.70, 0.98

Note: P-values: *$p < .05$; **$p < .01$; ***$p < .001$; **** indicates 95% *BC CI* is statistically significant with a probability of 95%.
[a]Sample size for depressive symptoms (M) =1,411. Depressive symptoms score was based on the total score of the 20 CES-D items while removing an item on restless sleep, a range between 0 and 57 for the analyses.

sleep duration (minutes/night) via depressive symptoms (β [Paths ab] = −2.22, 95% *BC CI* = −5.09, −0.25; and β = −1.94, 95% *BC CI* = −4.10, −0.35) (Table 3). Higher neighborhood violence and problems were significantly associated with higher depressive symptoms (Path a [violence]: β = 0.44, *SE* = 0.16, 95% *CI* = 0.13, 0.75, $p < .01$; problems: β = 0.38, *SE* = 0.11, 95% *CI* = 0.16, 0.60, $p < .001$). In turn, higher depressive symptoms were significantly associated with shorter sleep duration (Path b-Violence: β = −5.01, *SE* = 1.76, 95% *CI* = −8.47, −1.55; Problems: β = −5.11, *SE* = 1.76, 95% *CI* = −8.57, −1.65; and social cohesion: β = −5.03, *SE* = 1.76, 95% *CI* = −8.48, −1.58, all $p < .01$). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Similar patterns of associations for each path were observed for binary sleep quality outcome (Table 4). Only associations of neighborhood violence and problems (but not social cohesion) and sleep quality were significantly mediated by depressive symptoms.

Neighborhood violence and problems were significantly indirectly associated with short sleep duration (versus recommended) via depressive symptoms (OR [Paths ab] = 1.05, 95% *BC CI* = 1.00, 1.12; and OR = 1.05, 95% *BC CI* = 1.01, 1.10) (Table 5). Higher neighborhood violence and problems were significantly associated with higher depressive symptoms (Path a [violence]: β = 0.41, *SE* = 0.16, 95% *CI* = 0.09, 0.73, $p < .05$; problems: β = 0.38, *SE* = 0.11, 95% *CI* = 0.15, 0.60, $p < .01$). In turn, higher depressive symptoms were significantly associated with shorter sleep duration (Path b: OR = 1.12 or 1.13, 95% *CI* = 1.03, 1.23, all $p < .01$). None of the PNSE variables were associated with sleep duration (Path c' [direct effect] and Path c [total effect]). Similar patterns of associations for each path were shown for binary long sleep outcome (Table 6).

Discussion

This study of JHS participants, the largest community-based cohort study of African Americans, examined PA and psychosocial stressors as mediators of the relationships between PNSE factors and sleep duration and quality. The results showed the complex mechanisms in the associations between PNSE and sleep outcomes. When total PA, perceived stress, and depressive symptoms were examined as mediators in the separate models, this study demonstrated that those who reported higher perceived neighborhood violence and problems had shorter sleep duration, lower sleep quality, and a greater likelihood of reporting short duration (vs. recommended). In the case of lifetime discrimination as a mediator, higher neighborhood violence and problems were associated with longer sleep duration and high sleep quality, while higher social cohesion was related to shorter sleep duration and lower sleep quality. Furthermore, lifetime discrimination significantly and negatively mediated the associations of violence and problems with short sleep (vs. recommended), and positively mediated the association between social cohesion and short sleep. Opposite directions of mediated relationships were demonstrated for long sleep outcome. Furthermore, everyday discrimination did not mediate the associations between PNSE factors and sleep outcomes.

This study is one of the first to investigate the mediating role of PA on the associations between each PNSE and sleep outcomes, specifically among African American adults. Demonstrating the indirect mediation association between PA and sleep outcomes is crucial, especially in light of the evidence considering individuals who engage in higher PA had longer sleep duration, compared with those being sedentary [46].

The findings of **path a--**associations between each PNSE and PA, were consistent with the previous study [9], indicating that higher perceived violence and problems were related to lower PA levels, whereas higher social cohesion was linked to higher PA [9]. Consistent with what would be hypothesized (e.g. being physically active contributing to better sleep outcomes [47]), **path b** revealed that higher PA was associated with longer sleep duration, high sleep quality, and lower likelihood of engaging in short sleep (vs recommended). Mediation effects, **path axb**, may uncover the key role of PA for African American adults resulting to longer sleep duration, better sleep quality, and lower likelihood of engaging in short sleep, but not for long sleep (vs recommended). Despite the findings with small effect sizes, future research should also compare the findings from objectively measured PA and sleep, such as accelerometers, compared to self-reported sleep measure [48]. Furthermore, local efforts investing the development of PA promotion strategies implemented in a community could potentially yield a substantial impact at the population level. For example, local public health practitioners might offer information about PA resources such as group fitness classes and opportunities for PA participation at home for individuals perceiving adverse neighborhood conditions [47], which in turn, may contribute to better sleep health. From a neighborhood standpoint, vacant and blighted land use in a city has been perceived as risky and violent environments, experienced by many individuals in the U.S. Public health officials and policymakers could consider targeting to restore such vacant lots and spaces in a neighborhood to reduce violence, crime, and the perceived fear and increase safety in a community. These targeted community efforts could, in turn, increase PA levels among residents [49].

The results indicated unexpected directions of the associations between PNSE and sleep outcomes when testing for lifetime discrimination as a potential mediator. In the case of **path a**, participants who reported greater violence and problems had lower lifetime discrimination. In contrast, higher social cohesion was associated with greater lifetime discrimination. These findings might link to neighborhood socioeconomic position (SEP) [50] or neighborhood racial composition (i.e., similar to racial residential segregation) [51, 52]. For example, in a prior study, African American women who resided in the most deprived neighborhoods reported lower racial discrimination (through lifetime experience) and, in this cohort, women with lower education attainment appeared not to report racial discrimination [50]. A potential explanation for the opposite direction might also be that African Americans who reported greater violence and problems that may occur in more socioeconomically disadvantaged neighborhoods, may not encounter as much interpersonal racial discrimination due to less contact with individuals with different races [50]. In the case of **path b**, findings that higher lifetime discrimination with shorter sleep duration, lower sleep quality, greater likelihood of engaging short sleep (vs recommended), and lower likelihood of engaging in long sleep (vs recommended) were consistent with the previous studies [53, 54]. For example, a study using perceived discrimination and sleep quality in African American and White adults demonstrated that African Americans had lower sleep quality, compared to White adults, which was in part due to experiencing more discrimination [53]. Keeping this finding in mind, individuals experiencing discrimination as a source of stress could result in shorter sleep duration or low sleep quality, especially African American adults. Though mediation analyses reached statistical significance, the effect sizes were small. Overall positive mediation mechanism of **paths axb** reveals the complexity of mediation analyses that

individuals reporting greater violence and problems had better sleep outcomes, while opposite association was observed for social cohesion. It is possible that individuals who experience less discrimination within a homogeneous community, particularly African Americans, may feel safe in their neighborhoods. In turn, individuals with low level of discrimination can sleep better than those with experiencing greater discrimination within a heterogeneous neighborhood. Future research should consider accounting for the degree of heterogeneity of the residential neighborhood or segregation within a community [55].

Contrary to what would be expected, neither direct nor indirect mediation associations between each PNSE and sleep outcome were significant when testing for everyday discrimination mediator (e.g. being threatened or harassed). For null findings for everyday discrimination, a potential explanation may be accounted by the duration of residency in which participants reside in a certain neighborhood (e.g., racially segregated neighborhood [51, 52] or homogenous neighborhood SEP [50]). As a potential mediator, such chronicity of neighborhood contexts could impact the associations between PNSE and sleep outcomes. Furthermore, previous work has shown that disadvantaged neighborhood conditions (defined by neighborhood socioeconomic deprivation) yielded differential associations with cardiometabolic health outcomes based on duration of residence given the certain neighborhood [56].

The findings of **path a--**associations of each PNSE with perceived stress [57, 58] and depressive symptoms [59, 60], were consistent with previous studies. For instance, two studies using a sample of African American women demonstrated that women reporting greater perceived neighborhood physical disorder [58] and lower neighborhood social quality [57] reported greater perceived stress. Similarly, another study demonstrated that adverse neighborhood social context (e.g. exposure to chronic traffic noise) was associated with greater depressive symptoms among adults in Miami, Florida [59]. Taken together, the result from the previous studies [57–60] and the present study may suggest that living in adverse neighborhood social conditions (e.g. physical disorder, violence, problems) may have detrimental effects on perceived stress and depressive symptoms. In the case of **path b**, similar to what was demonstrated for lifetime discrimination [61], those reporting higher perceived stress and depressive symptoms had unfavorable sleep outcomes, which was consistent with prior research investigating the associations chronic stress [62] and depressive symptoms [63] with sleep outcomes. Collectively, the results from the prior studies and this study may imply that experiencing greater perceived stress and depressive symptoms may have harmful psychological impacts on sleep outcomes [20]. Overall mechanisms of indirect mediation effects, **paths axb**, were consistent with what would be postulated, where exposure to adverse neighborhood violence and problems were negatively associated with sleep outcomes through perceived stress and depressive symptoms, but not for social cohesion. In particular, the null finding of the association between social cohesion and sleep quality was inconsistent with the previous research [21]. The previous study indicated that lower neighborhood social cohesion was significantly associated with better sleep quality among African Americans [21]. Subsequently, the association was fully mediated by psychological distress, suggesting that low sleep quality due to increased psychological stress, which may lead to increased risk for depression and high states of vigilance [21]. These findings from previous research and the present study support chronic stress and depression as mechanisms connecting neighborhood violence and problems and sleep health, and such psychosocial stressors likely serve a crucial role impacting duration and quality of sleep among African American adults. However, these findings should be interpreted with caution due to the relatively small effect sizes. Future interventions could be tailored to provide information about accessible neighborhood resources to learn or improve how to manage and reduce stress for those perceiving neighborhood problems [64]. Thus, these programs and strategies may reduce individual's stress levels, which could improve sleep health.

There are several ways to test for mediation on the association between certain exposure and a certain outcome [44]. For instance, one JHS study on type 2 diabetes [30] tested mediation effects of PA, eating behavior, and BMI on the associations between neighborhood factors and type 2 diabetes. Analyses were performed by sequentially adding these mediators in the models. The authors found that adding BMI slightly attenuated the hypothesized associations [30]. They suggested using time-varying mediators and more rigorous mediation methodologies to understand the mechanism by which neighborhood factors are associated with type 2 diabetes and determine potential mediators. Another study investigated the associations between neighborhood conditions and sleep quality, and whether these associations may be mediated by psychosocial stressors among African Americans [21]. They used Baron and Kennys suggestion for conducting mediation analyses [65] with the Sobel test [66] (called "the normal theory approach" assuming the sampling distribution of axb being normal [44]) to determine statistical significance of the mediation. The normal theory approach has been widely used and fairly easily computed by hand; it is incorporated in structural equation modeling (SEM) programs [44]. However, the previous study had shown that the normal theory approach is less reliable compared to other alternative methods, such as the bootstrap confidence interval also known as resampling methods, which have more power than the normal theory approach [44].

Strengths and limitations

The strength of this study is that it contributes new knowledge to current literature by testing mediating roles of PA and psychosocial stressors on the links between each PNSE and sleep outcomes among the JHS participants. This study also utilizes a large, community-based cohort for the mediation analyses and uses standardized scales for data collection on PNSE, validated PA, and psychosocial stressors with high internal consistencies [35]. This study has several limitations that need to be addressed. First, the findings from this study may not be comparable to other African American adults, because the study sample was middle-aged and resides in a tri-county area of Jackson, Mississippi. Thus, the findings are not based on a nationally representative sample. Second, the baseline data were collected between 2000 and 2004. Thus, the generalizability of the findings from this study may not be reflected in the current social/cultural norms on sleep health (i.e. long screen time [67] due to smartphone use and tablet devices). Third, due to cross-sectional study design, this mediation study cannot infer causality of direct and indirect associations between PNSE and sleep outcomes. Fourth, multiple imputations may not be appropriate for the interpretation of the results. Thus, in the future, the full information maximum likelihood estimation in structural equation modeling may be alternative method to address missing values when performing mediation analyses. Lastly, this study used self-reported sleep duration and quality, which may lead to under- or overestimation, compared to objectively measured sleep duration [48]. Future research on sleep outcomes should also consider utilizing objective measures of sleep

outcomes. Yet, these neighborhood contextual measures were developed based on the application of empirical Bayes estimates at the census tract level [9]. Thus, this procedure has provided more suitable neighborhood-level contextual measures to reduce measurement errors at individual-level measures [29].

Conclusions

This study utilizing a large cohort of the JHS participants investigated the role of PA and psychosocial stressors as mediators. The results showed significant indirect mediation effects on sleep outcomes in relation to each PNSE through PA and psychosocial stressors. The present study revealed complex mechanisms of mediation effects on the associations between PNES and sleep outcomes, which need to be replicated in other large cohort studies, including longitudinal studies, to confirm such mediation effects on sleep health among African Americans.

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Ethics approval and consent to participate

The study was approved by the institutional review boards of the University of Mississippi Medical Center, Jackson State University, and Tougaloo College. All participants provided written informed consent. The National Institutes of Health Office of Human Subjects Research Protections approved our current study.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

KT and TPW made substantial contributions to the conceptualization of the work, drafted the work, and revised the work. KT performed all the analysis and interpretation of the data. SJN made all tables and figures. DAJ, SJN, and MS revised the manuscript and made substantial contributions to the interpretation of the data. All authors read and approved the final manuscript.

Data Availability

The data in the current study were obtained from the Jackson Heart Study (https://www.jacksonheartstudy.org/). These data are not publicly available, and its use is restricted.

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