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Broken Windows, Broken Zzs: Poor Housing and Neighborhood Conditions Are Associated with Objective Measures of Sleep Health

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Abstract African Americans and socioeconomically disadvantaged individuals have higher rates of a variety of sleep disturbances, including short sleep duration, poor sleep quality, and fragmented sleep. Such sleep disturbances may contribute to pervasive and widening racial and socioeconomic (SES) disparities in health. A growing body of literature demonstrates that over and above individual-level SES, indicators of neighborhood disadvantage are associated with poor sleep. However, there has been scant investigation of the association between sleep and the most proximal environments, the home and residential block. This is the first study to examine the association between objective and self-reported measures of housing and block conditions and sleep. The sample included 634 adults (mean age = 58.7 years; 95% African American) from two low-income urban neighborhoods. Study participants reported whether they experienced problems with any of seven different housing problems (e.g., broken windows) and rated the overall condition of their home. Trained data collectors rated residential block quality. Seven days of wrist actigraphy were used to measure average sleep duration, efficiency, and wakefulness after sleep onset (WASO), and a sleep diary assessed sleep quality. Multivariate regression analyses were conducted for each sleep outcome with housing or block conditions as predictors in separate models. Participants reporting "fair" or "poor" housing conditions had an adjusted average sleep duration that was 15.4 min shorter than that of participants reporting "good" or "excellent" conditions. Those reporting any home distress had 15.9 min shorter sleep and .19 units lower mean sleep quality as compared with participants who did not report home distress. Poor objectively measured block quality was associated with 14.0 min shorter sleep duration, 1.95% lower sleep efficiency, and 10.7 additional minutes of WASO. Adverse

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housing and proximal neighborhood conditions are independently associated with poor sleep health. Findings highlight the importance of considering strategies that target upstream determinants of sleep health disparities.

Keywords Sleep · Housing conditions · Neighborhoods · Disparities

Introduction

Sleep is a critical contributor to health and well-being [1–4]. There are significant racial/ethnic and socioeconomic disparities in Americans' sleep. African Americans and socioeconomically disadvantaged individuals have higher rates of a variety of sleep disturbances, including short sleep duration, poor sleep quality, and fragmented sleep [5, 6]. Sleep disturbances may contribute to racial and socioeconomic (SES) disparities in health. Therefore, understanding socio-environmental determinants of sleep health disparities is a public health imperative.

A growing body of literature demonstrates that, over and above individual-level SES, neighborhood-level factors including neighborhood SES and perceptions of neighborhood safety, cohesion, and disorder are associated with poor sleep [7–11]. However, the extant research has focused on fairly broad definitions of neighborhoods and sleep, while failing to consider more proximal neighborhood conditions, such as residential block quality, or the most proximal environment, the home [12–14]. Distressed housing conditions and poor residential block quality could negatively influence sleep by disrupting physical comfort and by heightening feelings of vigilance and psychological distress, which are opponent processes of sleep [7]. In contrast, well-maintained homes and residential blocks may contribute to feelings of safety and comfort, which should facilitate healthy sleep.

In a study of 371 low-income Latino residents, Chambers and colleagues [12] found that self-reported building problems (e.g., unpleasant smells; dark stairwells) were associated with more self-reported sleep disturbances, poor sleep quality, and longer time to fall asleep (i.e., sleep latency). A study of Latino farmworkers working in North Carolina [15] examined associations between a number of observer-coded housing problems (e.g., type of dwelling, presence of air conditioning) and self-reported sleep quality, and found that only air conditioning was associated with better sleep quality. This study is notable for its use of objective measures of housing conditions; however, the generalizability of the sample is limited as findings may not apply to other low-income individuals, African Americans, or urban residents. Only one study of indicators of housing conditions and sleep has involved African American and Caucasian adults [13]. The findings indicate that African American men and women living in houses/apartments were more likely to report being "short sleepers" (i.e., sleep duration < 7 h) relative to Caucasian counterparts. This study especially points to the need for further research on African Americans' sleep in particular, since they disproportionately live in disadvantaged neighborhoods characterized by suboptimal housing. Moreover, the small, extant literature on housing conditions and sleep has exclusively focused on self-reports of sleep, which provides a limited characterization of sleep [16]. Current conceptualizations of "sleep health" provide a more holistic view of sleep, which may be particularly relevant for identifying disparities in sleep. Specifically, sleep health is characterized by multiple domains of sleep characteristics, including duration, continuity, and quality, rather than isolated symptoms or the presence of disorders [17, 18].

In short, no one study has combined objective and subjective measures of sleep with measures of housing and proximal neighborhood conditions. The current study addresses this gap by examining the relationship between housing and residential block conditions and sleep among a sample of urban, low-income African Americans. We include important indicators of sleep health that are associated with health outcomes in prior work, including self-reported sleep quality, and actigraphy-assessed sleep duration, efficiency, and wakefulness after sleep onset (WASO) [19, 20]. We hypothesize that both resident perceptions of poor housing conditions and independent observations of poor block conditions would be associated with poorer sleep quality, shorter sleep duration, poorer sleep efficiency, and longer WASO, independent of known correlates of sleep problems and/or poor housing conditions including sociodemographics, body mass index (BMI), psychological distress, neighborhood-level crime, and neighborhood safety.

Methods

Study Design

Data for this study came from the PHRESH Zzz Study (Pittsburgh Hill/Homewood Research on Neighborhoods, Sleep, and Health), part of a longitudinal study that examines the effect of the built and social environment on health behaviors and risk factors in two low-income, predominantly African American Pittsburgh neighborhoods: the Hill District and Homewood. Households were randomly selected in each neighborhood at baseline (2011) and were followed through three follow-up waves of data collection (2013, 2014, 2016). The present analyses are based on data from 2016, when measures of housing quality were added to the survey and data collectors rated participants' residential blocks. Details of the study design, recruitment, and data collection procedures are described elsewhere [21, 22]. Data for the current analysis were collected via in-home interviews with participants (recruited originally as the main food shopper for the household), measured participant height and weight, actigraphy, sleep diaries, and data collector observations of residential blocks. All study protocols were approved by the RAND Corporation's Institutional Review Board.

Sleep Outcomes

The Actigraph GT3x+, a wrist-worn device that has been validated to measure sleep/wake rhythms relative to both polysomnography and Actiwatch, was used to provide objective assessments of sleep duration, efficiency, and WASO [23, 24].

As previously reported [11], participants were asked to wear the actigraph for seven consecutive days. Participants with fewer than four nights of actigraphy data were excluded from analyses, consistent with recommendations for the minimum nights required to establish reliable sleep-wake patterns via actigraphy [16]. Sleep outcomes were averaged across all available nights. The average number of nights of actigraphy for the analytic sample was 6.8, SD = 0.6, range = 4.0–7.0. Diary-reported bedtimes and waketimes were used to define the sleep interval, and further verified by visual inspection of the actigraphy tracings. Actigraphic data were scored using the GGIR R-Package which uses the raw accelerometer signal to identify sleep and wake periods. This scoring method has been validated against polysomnography and demonstrated 83% accuracy for identifying sleep and wake periods [25].

Sleep duration is the total amount of time spent sleeping during the participant's time in bed, assessed by actigraphy. Primary analyses treated sleep duration as a continuous variable. Secondary analyses examined a dichotomous "healthy sleep range" (i.e., 7–9 h; $N = 80$) versus short sleep duration (< 7 h; $N = 552$), given prior literature showing that short sleep duration is associated with adverse health outcomes [2]. Although long sleep duration (> 9 h) is also associated with adverse health outcomes, the sample size was too small to examine objectively measured "long sleepers" ($N = 2$). Therefore, in these secondary analyses, the two long sleepers were excluded.

Sleep efficiency is the total duration of actigraphy-measured sleep divided by the total time in bed (× 100) as reported in sleep diaries and visual inspection of actigraphy records. Higher values (expressed in percent) indicate better sleep continuity.

WASO is the total number of minutes scored as wake after sleep onset in actigraphy records. WASO was analyzed as a continuous variable, with higher values indicating more WASO.

Sleep quality. Participants completed daily diaries each morning upon awakening to provide assessments of *sleep quality* and to report their bedtimes and waketimes. Sleep quality was based on responses to a question asking participants to rate "how well you slept last night" on a 5-point Likert scale from "very poorly" to "very well," averaged across available nights. The average number of nights of sleep diary data was 6.9, SD = 0.4, range = 4.0–7.0.

Perceived Housing Conditions and Observations of Residential Block Quality

Perceived housing conditions and *housing distress* were captured using items drawn from the Moving to Opportunity study, a randomized controlled trial examining the impact of changes in neighborhoods (via housing vouchers) on recipients' health and well-being [26]. General perceived *housing conditions* were assessed using a single survey item that asks, "Overall, how would you describe the condition of your current home?" Due to the skewed distribution, response options were dichotomized by combining "Fair" and "Poor" versus "Excellent" and "Good." Participants were also asked if each of seven housing issues was "a

big problem", "a small problem", or "no problem at all" in their homes or apartments. The issues were [1] peeling paint or broken plaster, [2] plumbing that does not work, [3] rats or mice, [4] cockroaches, [5] broken locks or no locks on door to unit, [6] broken windows or windows without screens, and [7] a heating system that does not work. Due to low base rates for some of the individual items, we used a measure of *any housing distress*, scored as 1 if a participant reported that one or more of these seven issues was a small or big problem and 0 if a participant reported that all seven were no problem at all. Frequencies of individual housing items are reported in Table 1.

Objectively Measured Residential Block Conditions

Trained data collectors completed four items that rate the condition of each respondent's residential block to provide an objective assessment of proximal neighborhood conditions. Items were dichotomized as poor vs. not poor as follows: (1) "poor/badly deteriorated building condition" (peeling paint, broken windows) vs. "well-kept/good/fair condition"; (2) metal bars on windows on one or more buildings vs. no bars on windows; (3) poor street condition (e.g., potholes and other evidence of neglect) vs. "very good," "moderate," or "fair" street conditions (e.g., recent resurfacing, smooth; evidence of keeping in good repair; minor repairs needed but not rough surface); and (4) presence of major or minor trash accumulation vs. none. We created an overall measure of observed "poor block condition," scored as 1 if one or more items are rated as "poor" and 0 if no items were scored as "poor."

Covariates

Variables that are known to be associated with sleep disturbances and/or housing/neighborhood conditions were selected a priori as covariates, including household sociodemographics, psychological distress, measured BMI, perceived safety, and neighborhood-level crime.

Sociodemographic covariates collected through surveys included age, gender, household annual income, marital/cohabitation status (married or living with a partner versus living alone), education (categorized into less than high school, high school diploma (referent), some college, and college/bachelor's degree), presence of children in the home (any/none), and years lived in the neighborhood. We also statistically adjusted for

Table 1 Sample characteristics including objective and subjective sleep, housing conditions, block quality, and covariates

	Mean (SD) or %
Sleep measures	
Sleep duration, minutes	337.9 (75.6)
Efficiency, percent	73.5 (11.8)
WASO, minutes	109.7 (62.3)
Self-reported sleep quality (range 1–5)	3.7 (0.8)
Housing quality	
Self-reported overall housing conditions "Fair" and "Poor" (vs. "Excellent" and "Good")	29.5%
Participant reported any measure of housing distress	44.5%
Participant reports any problem with:	
Peeling paint or broken plaster	32.0%
Plumbing that does not work	17.4%
Rats or mice	9.8%
Cockroaches	4.1%
Broken locks or no locks on door to unit	5.5%
Broken windows or windows without screens	12.3%
A heating system that does not work.	9.1%
At least 1 of 4 objectively measured block quality items rated "poor"	64.3%
Objective measures rated "poor":	
General condition of buildings is "poor" or "badly deteriorated"	12.3%
Metal bars on windows	15.0%
Condition of the street is poor	8.8%
Any trash accumulation	58.1%
Covariates	
Age	58.7 (15.1)
Male	20.0%
Household annual income ($1000s)	21.3 (18.3)
Married/living with partner	15.9%
Education	
< High school	12.8%
High school	41.5%
Some college	33.4%
College	12.3%
Any children in household	22.7%
Years in neighborhood	31.1 (21.9)
BMI	30.9 (7.7)
Psychological distress (K6 scale)	4.4 (4.5)
Neighborhood	
Hill	70.0%
Homewood	30.0%
Perceived safety	3.0 (0.7)
Annual crimes within 1/10th of a mile of residence in 2016	23.8 (17.0)

Descriptives are reported for the sample ($N = 634$) with actigraphy. There were no significant differences in sample characteristics reported in Table 1 for the sample with sleep diaries ($N = 666$)

participants' neighborhood (Hill District or Homewood). We did not include race/ethnicity as a covariate because 95% of the sample self-identified as Black or African American.[1]

Psychological distress was measured using the Kessler 6 (K6) [27] scale, a well-validated self-report instrument. Respondents were asked how often in the past 30 days they felt [1] nervous, [2] hopeless, [3] restless or fidgety, [4] so depressed that nothing could cheer them up, [5] that everything was an effort, and [6] worthless. Response options ranged from 0 (None of the time) to 4 (All of the time). Responses were summed to create an overall score; higher scores indicate greater psychological distress (alpha = 0.85).

BMI was calculated from measured height (without shoes) and weight as weight in kg divided by height in m [3].

Perceived neighborhood safety was assessed using four items (i.e., "You feel safe walking in your neighborhood during the day," "You feel safe walking in your neighborhood during the evening," "Your neighborhood is safe from crime," and "Violence is a problem in your neighborhood") [28]. Response options for each item ranged from 1 (Strongly disagree) to 5 (Strongly agree). Items were reverse coded as necessary, and the composite was the mean of responses across items. Higher scores indicate higher perceived neighborhood safety (alpha = 0.67).

Total reported crime was estimated using incident-level data on crimes reported to the Pittsburgh Police Department and street network distances from each household to each approximate crime scene using ArcGIS 10.2 software. *Total reported crime* was the number of violent and property crimes that occurred within 1/10th mile of each participant's home in the study year.

Analytic Sample

A total of 751 participants in the Hill District and Homewood were part of the study in 2016. For analyses of actigraphy outcomes, we excluded 117 participants with less than 4 nights of actigraphy data. For analyses of sleep quality, we excluded 85 participants with less than 4 nights of sleep diary data. Therefore, the analytic sample size was 634 for objective sleep measures and 666 for self-reported sleep quality. Characteristics of study participants excluded due to missing or invalid data were not significantly different from those in the analytic sample.

Covariates were missing for between 0 and 5% of the sample, and missing values were imputed. Primary predictors were not imputed due to low rate of missingness (0–1.2% missing).

Statistical Analysis

First, we conducted descriptive statistics for all study measures. Second, we conducted separate multiple linear regression models predicting each sleep outcome by each housing or block condition measure, controlling for covariates. Third, we ran sensitivity analyses with either of the perceived housing measures and block conditions entered simultaneously to determine the independent effects of perceived housing and block conditions on sleep. Finally, we examined the relationship between housing or block conditions and the probability of being in the healthy sleep (7–9 h of sleep duration) versus short sleep range (less than 7 h of sleep duration), using logistic regression modeling. *P* value of 0.05 or less was used to determine statistical significance.

Results

Table 1 describes the sample characteristics for all study variables.

As shown in Table 2, self-reported "fair" or "poor" overall housing conditions were associated with 15.4 min shorter sleep duration, on average, compared with "excellent" or "good" conditions. Any home distress was associated with 15.9 min shorter sleep duration and 0.19 units lower sleep quality. Objectively measured poor block quality was associated with 14.0 min shorter sleep duration, worse sleep efficiency (1.95% lower) and higher WASO (10.7 min more), compared with good block quality. In sensitivity analyses that simultaneously entered either of the perceived housing measures and block conditions, results were similar to the original models, suggesting independent associations between housing and block conditions and sleep (analyses not shown). There were no statistically significant associations between any of the housing measures and

[1] We ran sensitivity analyses excluding the $N = 35$ participants who did not self-report race/ethnicity or who reported a race/ethnicity other than African American, and results were similar as with the full sample. Therefore, we present the analyses in the full sample.

Table 2 Multiple linear regression models predicting sleep outcomes[a]

	Actigraphy sleep outcomes ($n = 634$)			Sleep diary ($N = 666$)
	Sleep duration (minutes)	Efficiency (%)	WASO (minutes)	Sleep quality
Self-reported overall housing conditions "Fair" and "Poor" compared with "Excellent" and "Good"	− 15.42 (6.76)*	− 0.05 (1.08)	− 0.35 (5.78)	− 0.14 (0.07)
Any housing distress	− 15.91 (6.72)*	− 0.72 (1.04)	3.52 (5.58)	− 0.19 (0.07)**
Poor objectively measured block quality	− 13.96 (6.63)*	− 1.95 (0.99)*	10.69 (5.17)*	− 0.10 (0.07)

Note. Cells are B (SE); *$p < .05$, **$p < .01$; *SE*, standard error. Sample size may vary slightly in different models due to different rates of missingness for specific covariates; however, rates of missingness were low

[a] Results from separate models. Coefficients from only predictors of interest are shown

Covariates include age, gender, household annual income, marital/cohabitation status, highest level of education, presence of children in the home, length of time in neighborhood, neighborhood, psychological distress, BMI, perceived safety, and total crime

likelihood of being a short sleeper in logistic regression modeling (analyses not shown).

Discussion

The home environment is central to individuals' health and well-being. On average, Americans spend about 70% of their time inside their homes, with older adults being especially likely to spend more time inside their homes [29]. Substandard housing is more common in low-SES neighborhoods, and among African Americans—who disproportionately live in low-SES neighborhoods—are also more likely than whites to live in low-quality housing. This may also contribute to the Black/white health gap [30, 31]. Prior research has further demonstrated that suboptimal housing conditions are associated with adverse health conditions that disproportionately affect African Americans, including respiratory illnesses, cardiovascular diseases, and type 2 diabetes [30, 32]. Although there has been growing investigation of how broader neighborhood conditions associate with sleep [8, 10, 33], there has been relatively little emphasis on associations between more proximal neighborhood environments, such as housing or residential block conditions, and sleep. To our knowledge, this study is the first to show that the home environment—including perceived measures of housing conditions and observed residential block conditions—are independently and equally associated with objectively measured sleep duration and poor sleep quality among urban, African American residents.

Poor sleep health and poor housing and block conditions were prevalent in this sample. Average actigraphy-assessed sleep duration in this predominantly African American sample was 5.6 h. This is lower than the sleep duration reported in other national studies using actigraphy, but consistent with prior reports showing that African Americans have shorter sleep duration than non-Hispanic whites [34]. Residents' sleep was also fragmented, as indicated by an average sleep efficiency of 73% and over an hour and a half of wakefulness after sleep onset. To provide context, sleep efficiency less than 85% is often considered a threshold of treatment response in insomnia treatment studies [35].

Residents reported a variety of problems with housing conditions: most commonly peeling paint or plaster, problems with plumbing, and broken windows or windows without screens. Presence of trash accumulation and bars on windows were the most commonly objectively measured poor block conditions. Perceived housing problems or objectively rated poor block conditions could influence sleep by influencing physical comfort as well as feelings of safety and psychological well-being, which are critical for healthy sleep.

Indeed, multiple linear regression models showed that perceived housing distress and poor perceived housing conditions were associated with shorter sleep duration. Housing distress was also associated with poorer self-reported sleep quality. Our study was the first to include observations of the residents' housing block as well as objective measures of sleep, finding that poor block conditions were associated with shorter sleep duration, poorer sleep efficiency, and longer WASO. Importantly, these significant associations were

independent of other known factors that covary with sleep disturbances and/or suboptimal housing, including socioeconomic status, perceived safety, crime, and psychological distress. Further, significant associations between perceived housing and sleep persisted, even after adding block conditions to the model. However, it is possible that other unmeasured variables contributed to observed associations.

The current findings are consistent with the limited prior literature on housing conditions and self-reported sleep [12–15, 36, 37], and extend the literature by also demonstrating significant associations with objectively measured sleep duration and continuity. In addition, the current study is unique in that it focuses on residents from two predominantly African American, urban neighborhoods. Our focus on these neighborhoods in Pittsburgh is important because they are racially and socioeconomically segregated areas—a fundamental cause of health disparities. Finally, by including a host of individual and neighborhood-level covariates that may account for associations between housing and block conditions and sleep, our findings provide robust support for the contention that proximal neighborhood environments are an independent correlate of sleep health in a vulnerable population, and therefore, an important target of future intervention efforts.

The study has several limitations. First, while we included perceived measures of housing conditions, our objective measure of block quality provides an assessment of the proximal environment, but is not a direct measure of the exterior or interior of participants' individual homes. Further, the perceived and observational measures did not measure all housing conditions that are relevant for sleep. For instance, we did not have a measure of air conditioning, which has previously been associated with sleep quality [15]. Overcrowding may also be important for sleep; however, we did not expect this to be as important in this sample of middle-aged and older adults, many of whom were living alone and with less than 4% meeting the US Department of Housing and Urban Development criteria for overcrowding [38]. Although our inclusion of objective measures of block conditions is a strength, and we hired data collectors who were familiar with the neighborhoods (many of whom were residents themselves), observer ratings are also subject to bias and may be dependent on factors such as time of day or day of the week. Also, given the cross-sectional nature of the study, causal relationships cannot be ascertained. Finally, the findings were based on a cohort comprised primarily of African American women and may not generalize to other populations.

These findings highlight potential upstream determinants of sleep health disparities in African Americans, which may in turn contribute to other health disparities, including obesity-related morbidity and cardiovascular disease. Increased investments in municipal housing policies to reduce code violations, as well as grant and low-interest loan programs for weatherizing and modernizing homes could help landlords of privately owned affordable housing invest in the upgrades to make their apartments more habitable for their low-income tenants. While many cities offer variants of these programs with federal, state, or local dollars, they are generally underfunded [39, 40]. The current findings suggest that the benefit-cost calculus of programs to rehabilitate substandard housing should include sleep among the public health benefits of housing investment, which may translate into savings in health spending and a reduction in health disparities.

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References

1. Kerner NA, Roose SP. Obstructive sleep apnea is linked to depression and cognitive impairment: evidence and potential mechanisms. *Am J Geriatr Psychiatry*. 2016;24(6):496–508.
2. Knutson KL. Sleep duration and cardiometabolic risk: a review of the epidemiologic evidence. *Best Pract Res Clin Endocrinol Metab*. 2010;24(5):731–43.
3. Kojima M, Wakai K, Kawamura T, Tamakoshi A, Aoki R, Lin Y, et al. Sleep patterns and total mortality: a 12-year follow-up study in Japan. *J Epidemiol*. 2000;10(2):87–93.
4. Vgontzas AN, Fernandez-Mendoza J, Liao D, Bixler EO. Insomnia with objective short sleep duration: the most biologically severe phenotype of the disorder. *Sleep Med Rev*. 2013;17(4):241–54.
5. Jackson CL, Redline S, Emmons KM. Sleep as a potential fundamental contributor to disparities in cardiovascular health. *Annu Rev Public Health*. 2015;36:417–40.

6. Jean-Louis G, Grandner M. Importance of recognizing sleep health disparities and implementing innovative interventions to reduce these disparities. *Sleep Med*. 2016;18:1–2.
7. Hale L, Hill TD, Burdette AM. Does sleep quality mediate the association between neighborhood disorder and self-rated physical health? *Prev Med*. 2010;51(3–4):275–8.
8. Hale L, Hill TD, Friedman E, et al. Perceived neighborhood quality, sleep quality, and health status: evidence from the Survey of the Health of Wisconsin. *Soc Sci Med*. 2013;79:16–22.
9. Johnson DA, Billings ME, Hale L. Environmental determinants of insufficient sleep and sleep disorders: implications for population health. *Curr Epidemiol Rep*. 2018;5(2):61–9.
10. Johnson DA, Simonelli G, Moore K, et al. The neighborhood social environment and objective measures of sleep in the multi-ethnic study of Atherosclerosis. *Sleep*. 2017;40(1):zsw016.
11. Troxel WM, DeSantis A, Richardson AS, et al. Neighborhood disadvantage is associated with actigraphy-assessed sleep continuity and short sleep duration. *Sleep*. 2018;41(10):zsy140.
12. Chambers EC, Pichardo MS, Rosenbaum E. Sleep and the housing and neighborhood environment of urban Latino adults living in low-income housing: the AHOME study. *Behav Sleep Med*. 2016;14(2):169–84.
13. Johnson D, Thorpe R, McGrath J, Jackson W, Jackson C. Black–white differences in housing type and sleep duration as well as sleep difficulties in the United States. *Int J Environ Res Public Health*. 2018;15(4):564.
14. Liu Y, Njai RS, Greenlund KJ, Chapman DP, Croft JB. Relationships between housing and food insecurity, frequent mental distress, and insufficient sleep among adults in 12 US States, 2009. *Prev Chronic Dis*. 2014;11:E37.
15. Sandberg JC, Talton JW, Quandt SA, Chen H, Weir M, Doumani WR, et al. Association between housing quality and individual health characteristics on sleep quality among Latino farmworkers. *J Immigr Minor Health*. 2014;16(2):265–72.
16. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep.* 2003;26(3):342–92.
17. Buysse DJ. Sleep health: can we define it? Does it matter? *Sleep.* 2014;37(1):9–17.
18. DeSantis AS, Dubowitz T, Ghosh-Dastidar B, et al. A preliminary study of a composite sleep health score: associations with psychological distress, body mass index, and physical functioning in a low-income African American community. *Sleep Health*. 2019;5(5):514–20.
19. Dew MA, Hoch CC, Buysse DJ, Monk TH, Begley AE, Houck PR, et al. Healthy older adults' sleep predicts all-cause mortality at 4 to 19 years of follow-up. *Psychosom Med*. 2003;65(1):63–73.
20. Matthews KA, Kamarck TW, Hall MH, et al. Blood pressure dipping and sleep disturbance in African-American and Caucasian men and women. *Am J Hypertens*. 2008;21(7):826–31.
21. Dubowitz T, Ncube C, Leuschner K, Tharp-Gilliam S. A natural experiment opportunity in two low-income urban food desert communities: research design, community engagement methods, and baseline results. *Health Educ Behav.* 2015;42(1 Suppl):87S–96S.
22. Dubowitz T, Zenk SN, Ghosh-Dastidar B, Cohen DA, Beckman R, Hunter G, et al. Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutr*. 2015;18(12):2220–30.
23. Cellini N, McDevitt EA, Mednick SC, Buman MP. Free-living cross-comparison of two wearable monitors for sleep and physical activity in healthy young adults. *Physiol Behav*. 2016;157:79–86.
24. Quante M, Kaplan ER, Cailler M, et al. Actigraphy-based sleep estimation in adolescents and adults: a comparison with polysomnography using two scoring algorithms. *Nat Sci Sleep*. 2018;10:13.
25. van Hees VT, Sabia S, Anderson KN, Denton SJ, Oliver J, Catt M, et al. A novel, open access method to assess sleep duration using a wrist-worn accelerometer. *PLoS One*. 2015;10(11):e0142533.
26. Katz LF, Kling JR, Liebman JB. Moving to opportunity in Boston: early results of a randomized mobility experiment. *Q J Econ*. 2001;116(2):607–54.
27. Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med*. 2002;32(6):959–76.
28. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science.* 1997;277(5328):918–24.
29. Spalt EW, Curl CL, Allen RW, Cohen M, Adar SD, Stukovsky KH, et al. Time-location patterns of a diverse population of older adults: the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). *J Expo Sci Environ Epidemiol*. 2016;26(4):349–55.
30. Shaw M. Housing and public health. *Annu Rev Public Health*. 2004;25:397–418.
31. Do DP, Finch BK, Basurto-Davila R, Bird C, Escarce J, Lurie N. Does place explain racial health disparities? Quantifying the contribution of residential context to the Black/white health gap in the United States. *Soc Sci Med*. 2008;67(8):1258–68.
32. Schootman M, Andresen EM, Wolinsky FD, et al. The effect of adverse housing and neighborhood conditions on the development of diabetes mellitus among middle-aged African Americans. *Am J Epidemiol*. 2007;166(4):379–87.
33. DeSantis A, Troxel WM, Beckman R, et al. Is the association between neighborhood characteristics and sleep quality mediated by psychological distress? An analysis of perceived and objective measures of 2 Pittsburgh neighborhoods. *Sleep Health*. 2016;2(4):277–82.
34. Chen X, Wang R, Zee P, Lutsey PL, Javaheri S, Alcántara C, et al. Racial/ethnic differences in sleep disturbances: the multi-ethnic study of atherosclerosis (MESA). *Sleep.* 2015;38(6):877–88.
35. Edinger JD, Bonnet MH, Bootzin RR, Doghramji K, Dorsey CM, Espie CA, et al. Derivation of research diagnostic criteria for insomnia: report of an American Academy of Sleep Medicine Work Group. *Sleep.* 2004;27:1567–96.
36. Bano M, Chiaromanni F, Corrias M, et al. The influence of environmental factors on sleep quality in hospitalized medical patients. *Front Neurol*. 2014;5:267.

37. Peltz JS, Rogge RD. The indirect effects of sleep hygiene and environmental factors on depressive symptoms in college students. *Sleep Health*. 2016;2(2):159–66.
38. Blake KS, Kellerson RL, Simic A. *Measuring overcrowding in housing*. Washington, DC: Department of Housing and Urban Development, Office of Policy Development and Research; 2007.
39. Schwartz HL, Curtright AE, Ogletree C, Thornton E, Jonsson L. *Energy efficiency as a tool for preservation of affordable rental housing: evaluation of the efficiency emphasis in the MacArthur Foundation's window of opportunity initiative*. Santa Monica, CA: RAND Corporation; 2018.
40. Sissine FJ. *DOE weatherization program: a review of funding, performance, and cost-effectiveness studies*. Washington, D.C.: Congressional Research Service; 2012.