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Built Environment and Changes in Blood Pressure in Middle Aged and Older Adults

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Abstract

Objective—Few studies have examined interaction effects between person and environment, especially for cardiovascular disease (CVD) risk. The purpose of this study was to examine built environment characteristics and resident health behaviors as they relate to change in blood pressure, an important component of CVD.

Methods—Participants (N=1,145, aged 50–75 at baseline) were recruited from 120 neighborhoods in Portland, Oregon. Using a longitudinal design, we assessed changes in participants' systolic and diastolic blood pressure from baseline to 1-year follow-up (2006–2007 to 2007–2008). Independent variables included baseline neighborhood-level measures of GIS-constructed neighborhood walkability and density of fast-food restaurants, and resident-level measures of meeting physical activity recommendations and eating fruits and vegetables.

Results—There was a small but significant resident-level increase in both systolic and diastolic blood pressure ($P<0.001$) over the 1-year observation period. A similar trend was also observed at the neighborhood level ($P<0.001$). Significant differences in change in blood pressure, by neighborhood walkability, were observed, with decreases in systolic and diastolic blood pressure for those living in high walkable neighborhoods (P<0.001). Neighborhoods of low walkability but with a high density of fast-food outlets and residents making visits to fast-food restaurants were significantly associated with increases in blood pressure measures over time. The negative effect of fast-food restaurants on blood pressure was diminished among high-walkable neighborhoods, with benefits observed among residents meeting guidelines for physical activity and eating fruits and vegetables.

Conclusions—Neighborhoods with high walkability may ameliorate the risk of hypertension at the community level and promotion of neighborhood walkability could play a significant role in improving population health and reducing CVD risk.

Keywords

blood pressure; prospective study; urban health

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Conflict of Interest

The authors have no conflict of interest to declare.

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Introduction

Cardiovascular disease (CVD), a family of pathologies that includes hypertension, coronary heart disease, and stroke, is the leading cause of death worldwide (World Health Organization, 2003), including in the United States (Center for Disease Control and Prevention, 2007). It is also a major source of disability and ill health, and the associated social and economic costs are high (Center for Disease Control and Prevention, 2007; World Health Organization, 1997a). Although compelling evidence has identified a number of risk factors for CVD (Dishman, Washburn, and Heath, 2004), most of which are closely related to lifestyle (USDHHS, 1996; World Health Organization, 1997b), there is relatively little research documenting the role that the built environment plays in influencing and/or moderating CVD risk.

Environmental characteristics, including aspects of urban form, neighborhood safety, social capital and food availability, have received increased attention as they are related to physical activity, obesity, mobility disability, and CVD (Berke et al., 2007; Clarke et al., 2008; Diez Roux, 2003; Ewing et al., 2003; Fisher et al., 2004; Frank et al., 2004; Frank et al., 2005; Gauvin et al., 2008; Li et al., 2005; Li et al., 2008; Li et al., 2009; Li et al., in press; Lopez, 2004; Maddock, 2004; Mehta and Chang, 2008; Mobley et al., 2006; Morland, Diez Roux, and Wing, 2006; Mujahid et al., 2008; Mujahid et al., 2008; Owen et al., 2007; Rundle et al., 2007). Evidence to date suggests that the built environment can either positively influence health behaviors or be a health stressor. For example, urban environment characteristics such as greater population density, more street connectivity (higher intersection density or walkability), and higher land use mix (i.e., the degree to which residences, businesses and green spaces are integrated within neighborhoods) are associated with more walking or bicycling activities (Berke et al., 2007; Li et al., 2005; Li et al., 2008; Owen et al., 2007; Saelens et al., 2003), as well as less obesity (Frank et al., 2005; Li et al., 2008; Li et al., in press). With respect to CVD risk, limited research has shown that people living in better land use mix areas tend to be associated with a lower probability of being hypertensive (Mujahid et al., 2008) and lower coronary heart disease risk (Mobley et al., 2006). Conversely, sprawling areas are likely to have a higher prevalence of hypertension (Ewing et al., 2003).

The aims of this study were to examine environmental characteristics that may influence, either directly or interactively, hypertension, an important component of CVD. We chose blood pressure because of its public health significance as a primary or contributing cause of death for Americans (Centers for Disease Control and Prevention, 2007). To address the study aims, we first tested the general working hypothesis that neighborhoods with high walkability would be associated with reduced blood pressure values whereas neighborhoods with higher densities of fast-food restaurants would be associated with increased blood pressure over time. Next, we tested the moderating hypothesis that the effect of the density of fast-food restaurants on blood pressure would become weak or inconsequential when neighborhood walkability is high and residents within neighborhoods engage in healthy behaviors.

Methods

Study Design and Population

The study used a prospective, multilevel design. Residents aged 50–75 living in the Portland, Oregon metropolitan region’s urban growth boundary (UGB) formed the population of the Portland Neighborhood Environment and Health study, which has been described in detail elsewhere (Li et al., 2008). From this sampling framework, 1,221 participants were randomly recruited from a randomly selected sample of 120 Census block groups (a median of nine participants per neighborhood; range 5–21). Participants completed baseline assessments

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(2006–2007) which included surveys of health, physical activity, dietary intake, and anthropometric measures. Participation rate among those screened and deemed eligible was 48%. Participants were reassessed at a 1-year follow-up (2007–2008) (average follow-up =11.5 months). In the current study, data from 1,145 participants, who completed the 1-year follow-up (94% of the original sample at baseline), were analyzed. There were no differences between those included in the current study versus those who were excluded with respect to major demographics characteristics (Li et al., in press). This study was approved by an Institutional Review Board and informed consent was obtained from all participants.

Assessment of Blood Pressure

Resting blood pressure measurements were collected using commercially available blood pressure monitors (Omron™ HEM-780N) and performed by trained research assistants. Measures were taken twice (approximately 5 minutes apart) in a seated position in a quiet office environment after the participant had rested 5 minutes. The mean values for systolic and diastolic pressure were used to define blood pressure values.

Resident-level Measures

Physical activity—At baseline, Behavioral Risk Factor Surveillance System survey questions were used (Center for Disease Control and Prevention, 2008) to assess the sum of weekly moderate and vigorous physical activity by frequency (number of days) and duration (in minutes). Moderate activities were defined as engaging in, for at least 15 minutes at a time, activities such as brisk walking, bicycling, vacuuming, gardening, or anything else that led to some increased breathing or heart rate. Vigorous activities were defined as engaging in, for at least 10 minutes at a time, activities such as running, aerobics, heavy yard work, or anything else that led to large increases in breathing or heart rate. Values of these physical activity measures were multiplied to provide the total number of minutes of each activity in a usual week (7 days). Physical activity levels (min/wk) were further classified, per guidelines (Haskell et al., 2007; Nelson et al., 2007; Pate et al., 1995), into two categories: (a) meets recommendations; and (b) insufficiently active or inactive.

Fruit and vegetable intake—The “All-Day” version of the Fruit and Vegetable screener (Thompson et al., 2000) was used at baseline to assess the frequency and portion size of fruits and vegetable consumption. The screener includes 10 questions that ask participants how often fruit and vegetables were consumed in the past month. Scores were computed per scoring guidelines established by the National Cancer Institute (NCI, 2008), with higher scores indicating higher levels of fruit and vegetable intake.

Eating-out behavior—At baseline, participants’ weekly local fast-food restaurant consumption was assessed via the questions of (a) “How often do you eat food from a place like McDonalds, Burger King, KFC, Pizza Hut, or some other fast-food restaurant?” and “How often do you go to buffet-type restaurants?” The two-item scale has a 12-month test-retest reliability of 0.75 and excellent validity (Li et al., 2009). Responses were recorded as: (1) never, (2) less than once per week, (3) 1–2 times a week, (4) 3–4 times a week, (5) five times a week, and (6) every day. In our analyses, a categorical variable was made with 1 being visiting 1–2 times or more each week and 0 being never or less than once per week.

Sociodemographic and anthropometrics—All measures were collected at baseline. Neighborhood-level measures included residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents, and were derived from the 2000 Census data. The resident-level measures included sociodemographic measures of age, gender, education, household income, alcohol use, tobacco use, hypertension-related medication use, and objective anthropometric measures of body height and weight,

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which were then used to compute body mass index (BMI), calculated as weight (kg)/height $(m)^2$.

Neighborhood-level Measures

Geographic data were provided by the Regional Land Information System (www.metro-region.org) which contains current street centerline files and other important geographic data layers (e.g., tax assessor's data, regional land use data from digital aerial photography, employment data, 2006 census data). The data used in this study were spatially integrated within a Geographic Information System (GIS), using ArcView (version 9.2, Environmental Systems Research Institute, Redlands, CA). All environmental measures were taken at baseline.

Walkability—A walkability index was calculated on the basis of a composite score consisting of land use mix, street connectivity, number of public transit stations, and amount of green and open spaces (Li et al., 2008). Following normal practice (Berke et al., 2007; Frank et al., 2004; Mobley et al., 2006; Owen et al., 2007), scores from these four variables were standardized, summed, and the final scores were divided into percentiles, with scores ≥ 75th percentile coded as high walkable neighborhoods, and below indicating low walkable neighborhoods.

Density of fast-food restaurants—Information on types of fast food restaurants was obtained via a commercially purchased business dataset (http://infousa.com), and subsequently compiled using proprietary 4-digit extensions to the Standard Industrial Classification codes. Included were various fast food chain restaurants such as McDonald's, Burger King, and Wendy's. A density score was calculated by dividing the number of fast-food restaurants by square miles within each neighborhood. All records were successfully geocoded, with 94% matched to the street address. The resulting density scores were further divided into ≥75th percentile (defined as high density) and <75th percentile (defined as low density).

Using census data, four other neighborhood-level variables were included: residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents.

Statistical Analysis

The dependent variables in this study were changes in systolic and diastolic blood pressure. To examine change, within-group paired t tests were performed to examine change from baseline to 1-year follow-up in blood pressure across both resident-level (N=1,145) and neighborhood-level (N=120) samples, and independent t tests were performed to examine differences in change in blood pressure between high and low walkable neighborhoods across both levels of the study samples. Major analyses were performed using multilevel model methodologies and conducted in two steps. In Step 1, a single-group multilevel model was estimated simultaneously for the two dependent variables to test the hypothesis that neighborhood walkability and density of fast-food restaurants were related to change in blood pressure. In the multilevel model, the between-level predictors included: neighborhood walkability, density of fast-food restaurants, and demographic covariates (residential density, median household income, and percentage of non-Hispanic black residents, and percentage of Hispanic residents). The within-neighborhood predictors included the following resident-level variables: meeting recommended levels of physical activity, eating fruit and vegetables, age, gender, education, household income, alcohol and tobacco use, fast-food restaurant visits, and BMI. In Step 2, we split the neighborhood sample on the basis of high (≥75th percentile) and low (<75th percentile) walkability to test the moderating hypothesis of neighborhood

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walkability on the relation between density of fast-food restaurants and change in blood pressure. A multilevel model was then tested using a multisample procedure (Rigdon et al., 1998) in which the interacting variable of walkability was defined by high and low walkability samples. In the multilevel model, each blood pressure outcome variable was regressed on density of fast-food restaurants and other covariates (described previously) at the neighborhood level, and on meeting recommended levels of physical activity, fruit and vegetable intake, fast-food restaurant visits and other covariates (described previously) at the resident level. The interaction effect was evaluated by testing a model in which the parameters in question (i.e., the effect of density of fast-food restaurants on blood pressure) were constrained to be equal across the two samples, and then estimated in a second model in which the parameters were allowed to be different in the two samples. Significance was determined by chi-square statistic tests. Multilevel analyses were performed using M*plus* (version 5.1, Muthén and Muthén, 1998–2004).

Results

Participants (656 males, 489 females) ranged in age from 50 to 75 years at baseline and had lived in their current residence for an average 8.5 years. Blood pressure in the study sample fell within the pre-hypertension category (120–139 mmHg systolic; 80–89 mmHg diastolic) per established guidelines (National Institutes of Health, 2008). At baseline, thirty-seven percent of the participants reported use of blood pressure-related medication and the percentage increased slightly (38.5%) by the 1-year follow-up. Overall, there were no significant changes in medication use (i.e., number of medications used related to chronic conditions such as hypertension, heart disease, lung disease, diabetes) among the participants over the study period (Ps > 0.23).

Key baseline sample characteristics by walkability both at the resident- and neighborhood-level are shown in Table 1. There were no statistical differences in blood pressure by socioeconomic status of the study neighborhoods with the exception that low-walkable neighborhoods of low-median household income tended to have higher systolic blood pressure compared to those of high-median household income (137 vs. 134 mm Hg, $P < 0.05$).

There was a small but significant increase, at the resident level in both systolic (2.38 mm Hg, $P<0.001$) and diastolic (1.41 mm Hg, $P<0.001$) blood pressure over the 1-year observation period. A similar trend was observed at the neighborhood level for systolic, 2.74 mm Hg ($P<0.001$) and diastolic 1.63 mm Hg ($P<0.001$). Table 2 presents the resident- and neighborhood-level change scores in blood pressure, by neighborhood walkability, from baseline to 1-year follow-up. Significant differences in change in blood pressure, by neighborhood walkability, were also noted, with a moderate increase in systolic and diastolic blood pressure for those living in low walkable neighborhoods.

Results from the single-group multilevel analyses indicated that, controlling for the level-specific covariates, neighborhoods with high walkability were shown to be a significant predictor of a decrease in both systolic ($\beta=-6.99$, $P<0.001$; where β is the unstandardized beta weight) and diastolic ($\beta= -4.95$, $P<0.001$) blood pressure over time. In contrast, high density of fast-food restaurants was predictive of an increase in systolic ($\beta=5.32$, $P<0.001$) and diastolic ($\beta=2.21$, $P<0.001$) blood pressure over time. The neighborhood-level bi-variate relationship between walkability and density of fast-food restaurants was 0.41 ($P<0.001$)

Results from the multisample multilevel regression analyses (effect estimates) provided further delineation of the neighborhood walkability effect (Table 3). The chi-square difference was significant ($P<0.05$) suggesting that the equality constraints imposed were not consistent with the data, and thus that an interaction effect existed. For the high-walkable neighborhoods,

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density of fast-food restaurants was no longer predictive of change in blood pressure (*P*=0.86 for systolic, *P*=0.85 for diastolic) at the neighborhood level. However, the resident-level predictors of both meeting recommended levels of physical activity and fruit and vegetable intake were predictive of a significant reduction in blood pressure at the within-neighborhood level. In contrast, for the low walkable neighborhoods, density of fast-food restaurants was significantly related to increases in systolic (*P*<0.001) and diastolic (*P*<0.01) blood pressure over time. Neither resident-level predictors of meeting recommended physical activity nor eating fruits and vegetables were significantly related to the change in blood pressure. However, weekly visits to local fast-food restaurants were significantly related to increases in systolic (β=3.11, *P*<0.05) and diastolic (β=1.94, *P*<0.05) blood pressure. All analyses controlled for both resident and neighborhood-level covariates.

Discussion

Our findings indicate that low neighborhood walkability and high density of fast-food restaurants were both significantly related to increases in systolic and diastolic blood pressure over time. However, new findings from the current study point to the important role of neighborhood walkability in moderating the often-reported negative impact of fast-food availability on CVD risk, specifically hypertension. Our results show that for neighborhoods with low walkability, there is a strong influence of density of fast-food restaurants on change (increases) in blood pressure over time. In other words, among low-walkable neighborhoods, high density of fast-food restaurants is associated with a greater increase in blood pressure over time. This effect may be further exacerbated by frequent visits to local fast-food restaurants.

The non-significant relationship observed between density of fast-food restaurants and change in blood pressure for neighborhoods with high walkability is equally important. Specifically, in support of our hypothesis, we have shown that density of fast-food restaurants exerts little or no significant impact on increasing blood pressure among high-walkable neighborhoods. Beyond the neighborhood effect, our findings further show that residents’ healthy lifestyles (i.e., meeting physical activity recommendations and eating more healthy food) positively impact change in blood pressure over time.

Implications

Our findings have important urban planning and public health implications. First, public health efforts aimed at reducing urban health risk need to focus on improving built environment features related to neighborhood walkability. Efforts to either increase connected street networks or maximize mixed land use would appear most beneficial for increasing neighborhood active living potential so that residents may become more physically active and, ultimately, reduce adverse health consequences such as hypertension. This will require collaboration between disciplines such as public health, urban planning and transportation. An integrated approach can help identify the best practices for promoting the most livable communities through initiatives to promote healthy neighborhood environments. Additionally, community-wide educational campaigns to encourage residents to engage in health-enhancing behaviors, including increased physical activity and healthy eating practices, are required.

Study Limitations and Strengths

There are some limitations to this study. First, our blood pressure measures were taken during a single visit at both baseline and follow-up, which may entail potential measurement errors due to unmeasured confounders such as caffeine use, white coat hypertension or masked hypertension. Similarly, the use of self-reported physical activity and fruit and vegetable measures may also have introduced measurement biases. The use of objective measures (e.g.,

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accelerometers) would allow us to assess the relationships under investigation more rigorously and enhance the validity of the findings. Second, although longitudinal data were analyzed, the short (1 year) period and two-point observations limit capturing the rate of change in blood pressure at either neighborhood or resident levels. Relatedly, the use of cross-sectional built environment data precludes the analysis of change in built environment in relation to change in hypertension, which will be of great importance in developing policies and urban design initiatives for creating healthy living communities. Third, while the level of neighborhood walkability was shown to ameliorate the relationship between density of fast-food restaurants and blood pressure outcomes, the composite index (of walkability) may have masked certain salient roles that a particular element of the index, such as street connectivity or pubic transit stops, may have in directly or interactively influencing blood pressure status, suggesting the need to conduct more delineated analyses to study specific aspects of this global index on health outcomes. Lastly, blood pressure is only one aspect of CVD. Other measures such as high blood cholesterol, smoking, or obesity/overweight, should be incorporated in future studies.

The study also has several strengths. First, the age cohort of the study sample is unique in that it utilizes urban middle-aged and older adults of the immediate pre-baby boom/early-baby boom generations, which not only will become the major demographic related to healthcare utilization in the next 20 years but also has the highest risk for CVD, including hypertension. Second, the use of a multilevel and prospective design allowed us to have a more rigorous examination of both neighborhood and resident level influences over time while controlling for level-specific confounders. It is also worth noting that our sampling frame focuses on the much smaller geographic unit of neighborhood (defined by census block group) than the geographic scale most often reported in the literature (e.g., metropolitan, Zip code or county) (Gauvin et al., 2008; Mehta and Chang, 2008; Mobley et al., 2006; Eid, Overman, Puga, and Turner, 2008). The use of small scale neighborhoods for research may increase the direct policy applicability of the study results.

Conclusions

The current study adds to the nascent research on built environment and health by showing that neighborhood walkability, combined with resident healthy behaviors, can reduce the impact of an unhealthy food environment on blood pressure. Findings suggest urban developers and designers, and health professionals must consider the built environment features of neighborhood walkability, such as mixed-land use and street connectivity, to create communities that positively impact hypertension by being more conducive to healthy living.

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Table 1

Study Resident (N = 1,145) and Neighborhood (N = 120) Sample Characteristics at Baseline by Neighborhood Walkability Index[a], Portland (Oregon, USA) Neighborhood Environment and Health Study, 2006–2007

	High-Walkable	**Low-Walkable**	
Resident-Level Measures	**Mean (SD)[b]**	**Mean (SD)[b]**	**P Value**
		Baseline (2006–2007)	
Age in years	62.5 (6.7)	61.8 (6.9)	0.14
Systolic blood pressure (mm (Hg)	133.51 (15.84)	134.72 (16.89)	0.29
Diastolic blood pressure (mm Hg)	81.09 (9.92)	80.59 (10.14)	0.47
Body mass index[c]	29 (6)	29 (6)	0.38
Health status (No. %)			
Poor to fair	46 (17)	136 (16)	
Good to excellent	226 (83)	737 (84)	0.6
Meeting physical activity recommendation (No. %)			
Meet	154 (57)	519 (58)	
Not meet	118 (43)	354 (42)	0.41
Eating fruit and vegetable	6.3 (4.4)	6.2 (4.0)	0.72
Visiting fast-food restaurants[d] (No. %)			
Yes	53 (19)	216 (25)	
No	219 (81)	657 (75)	0.07
Neighborhood-Level Measures			
Average residents per neighborhood	23322 (28398)	19308 (20457)	0.40
Household density (household per square mile)	30435 (23573)	21920 (10976)	0.008
Median household income ($)	40669 (16323)	49131 (17409)	0.05
Percentage of African American (%)	5.22 (7.37)	3.48 (6.03)	0.19
Percentage of Hispanic (%)	7.5 (9.3)	5.94 (5.04)	0.22

[a] High scores represent high walkable neighborhoods.

[b] Standard deviation

[c] Computed as weight (kg)/height (m)^2.

[d] Response to “Yes” is coded as 1 (i.e., visiting 1–2 times or more each week) and “No” coded as 0 (i.e., never or less than once per week).

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Table 2

1-Year Change in Systolic and Diastolic Blood Pressure at Both Resident- (N = 1,145) and Neighborhood-Level (N = 120) (by Neighborhood Walkability), Portland (Oregon, USA) Neighborhood Environment and Health Study, 2006–2008

	Resident-level: 1-year change (baseline to follow-up: 2006–2007 to 2007–2008)		
	High walkability	**Low walkability**	**Group difference**
Systolic blood pressure (mm Hg) (Mean; SD)	−1.02 (15.89)	3.44 (17.63)	−4.46[a]
Diastolic blood pressure (mm Hg) (Mean; SD)	−1.35 (11.77)	2.27 (11.21)	−3.63[a]
	Neighborhood-level: 1-year change (baseline to follow-up: 2006–2007 to 2007–2008)		
	High walkability	Low walkability	Group difference
Systolic blood pressure (mm Hg) (Mean; SD)	−0.26 (7.07)	3.75 (7.19)	−4.01[a]
Diastolic blood pressure (mm Hg) (Mean; SD)	−1.28 (2.62)	2.61 (5.60)	−3.89[a]

[a] Statistically significant between high and low walkable neighborhoods (*P* < 0.001).

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Table 3

Multilevel Regression Analysis of Change in Blood Pressure over a 1-YearPeriod by Built Environment and Personal Lifestyle Characteristics,[a] Portland (Oregon, USA) Neighborhood Environment and Health Study, 2006–2008

	Blood pressure							
Regression estimate (beta weight)	**Systolic β (95%% CI)**	**P**	**Diastolic β (95%% CI)**	**P**	**Systolic β (95%% CI)**	**P**	**Diastolic β (95%% CI)**	**P**
	High walkability				Low walkability			
Between-neighborhood predictor								
Density of fast-food restaurants	−0.17 −1.9,1.6	0.86	−0.17 −1.9,1.6	0.85	8.65 5.1,12.2	<0.001	4.07 1.05,7.1	0.008
Within-neighborhood predictor								
Meeting recommendations	−6.90 −10.9, −2.8	0.001	−3.26 −6.2, −1.3	0.03	1.31 −1.1,3.7	0.30	0.67 −0.80,2.12	0.37
Eating fruit and vegetable	−0.70 −1.4, −0.08	<0.05	−0.48 −0.93, −0.29	<0.05	−0.08 −0.31,0.27	0.91	−0.10 −0.24,0.04	0.14
Visits to fast-food restaurants[b]	0.90 −4.2,6.1	0.73	0.81 −2.7,4.4	0.66	3.11 0.19,6.0	<0.05	1.94 0.17,3.70	<0.05

[a] Analyses adjusted for neighborhood- and resident-level sociodemographic characteristics and medication use at baseline, including age, gender, education, household income, race/ethnicity, alcohol use, smoking, and blood pressure medications at the resident-level, and residential density, median household income, percentage of non-Hispanic black residents, and percentage of Hispanic residents at the neighborhood level.

[b] Response to “Yes” is coded as 1 (i.e., visiting 1–2 times or more each week) and “No” coded as 0 (i.e., never or less than once per week).