Longitudinal Assessment of Urban Form and Weight Gain in African-American Women

Patricia F. Coogan, ScD, Laura F. White, PhD, Stephen R. Evans, MPH,
Thomas J. Adler, PhD, Kevin M. Hathaway, MS, Julie R. Palmer, ScD, Lynn Rosenberg, ScD

Background: Numerous cross-sectional studies have found higher levels of obesity among residents of auto-oriented, sprawling areas compared to residents of more urban areas.

Purpose: The association between neighborhood urban form and 6-year weight change was prospectively analyzed in the Black Women's Health Study, a cohort study of U.S. black women who enrolled in 1995 and are followed biennially with mailed questionnaires.

Methods: The analysis included 17,968 women who lived in New York City, Chicago, or Los Angeles and were followed from 1995 to 2001. Factor analysis was used to combine variables describing the urban form of participants' residential neighborhoods into an "urbanicity" score. Mixed linear regression models were used to calculate least-squares means for weight change across quintiles of the urbanicity score. Incidence rate ratios (IRRs) and 95% CIs for incident obesity in relation to the urbanicity score among women who were not obese at baseline were derived from Cox regression models. All results were adjusted for age, region, lifestyle factors, and neighborhood SES. Analyses were conducted in 2008–2010.

Results: In multivariate analysis, mean weight gain for women in the highest quintile of urbanicity score (most urban) was 0.79 kg less than for those in the lowest quintile, with a significant trend (p=0.003). The IRR for incident obesity in the highest quintile relative to the lowest was 0.83 (95% CI=0.71, 0.97), with a significant trend (p=0.042).

Conclusions: Policies that encourage dense, urban residential development may have a positive role to play in addressing obesity in black women.
(Am J Prev Med 2011;40(4):411–418)

Background

Numerous cross-sectional studies have found higher levels of obesity among residents of auto-oriented, sprawling areas compared to residents of more urban areas. At the metropolitan scale, levels of overweight and obesity are higher among residents of counties with high indices of sprawl compared to residents of less-sprawling counties.[1–4] Studies at smaller geographic scales have also found that traditional neighborhoods characterized by higher density,[5–7] older housing stock,[7] highly interconnected streets,[5,7,8] public transit availability,[6] and a mix of land uses[6,9–13] have lower levels of overweight and obesity than do more auto-oriented neighborhoods.

Cross-sectional studies cannot determine the temporal sequence of neighborhood exposures and weight gain, and there is possible selection bias as well.[14] In prospective studies, neighborhood characteristics predate weight gain and obesity incidence; although selection bias is possible, there can be better control for confounding because the temporal sequence of exposure, risk factors, and weight gain is known. Thus far, three prospective analyses have been conducted within the U.S. National Longitudinal Survey of Youth (NLSY): in one analysis, moving to a low-sprawl county was associated with weight loss,[4] whereas in the two other analyses of NLSY data there was no association between sprawl and weight change.[15,16]

The health burden of obesity is severe among African-American women: In National Health and Nutrition Examination Survey (NHANES) data from 2003–2004, 28% of black women were overweight ($25\leq$ BMI<30); 39% were obese ($30\leq$BMI<40); and 15% were severely obese

From the Slone Epidemiology Center (Coogan, Palmer, Rosenberg), the Department of Biostatistics (White), Data Coordinating Center (Evans), Boston University, Boston, Massachusetts; and Resource Systems Group, Inc. (Adler, Hathaway), White River Junction, Vermont

Address correspondence to: Patricia F. Coogan, ScD, Slone Epidemiology Center at Boston University, 1010 Commonwealth Avenue, Boston MA 02215. E-mail pcoogan@bu.edu.
0749-3797/$17.00
doi: 10.1016/j.amepre.2010.12.013

(BMI ≥40); comparable figures for white women were 28%, 24%, and 6%, respectively.[17] Compared to white women, African-American women also have higher prevalence of the consequences of obesity, including stroke,[18] hypertension,[19] and diabetes.[20]

To test the hypothesis that women living in urban neighborhoods would gain less weight over 6 years of follow-up than women living in suburban or rural neighborhoods, the association between urban form and 6-year change in weight and incidence of obesity was prospectively analyzed among Black Women's Health Study (BWHS) participants. In previous analyses of BWHS data, participants who lived in dense urban neighborhoods were more likely to walk for transport (i.e., to a destination) than women who lived in less-dense neighborhoods.[21]

Methods

The Study Population

The BWHS is a prospective cohort study established in 1995 when approximately 59,000 African-American women aged 21–69 years were recruited mainly from subscribers to *Essence* magazine, a general readership magazine whose subscribers are predominantly African-American women. The cohort is followed biennially by mailed questionnaire, and follow-up has averaged more than 80% of the original cohort through five questionnaire cycles. The study was approved by the IRB of Boston University.

The present analysis included BWHS participants who lived in the New York, Chicago, or Los Angeles metropolitan regions at baseline in 1995 (n=20,795). Study boundaries included areas ranging from urban to rural. Follow-up for the present analysis began at baseline in 1995 and continued through 2001. The analytic cohort excluded 61 participants who reported gastric bypass surgery, 191 who reported incident cancer over follow-up, 226 who were missing baseline height or weight, 153 with baseline weight ≥300 pounds, and 2196 whose addresses could not be geocoded, for a final population of 17,968 individuals. Seventy percent of the women contributed 6 years of follow-up, 14% contributed 4 years of follow-up, and 16% contributed 2 years of follow-up for a total of 91,270 person-years of follow-up. Analyses were conducted in 2008–2010.

Ascertainment of BMI and Change in Weight

Data on height and weight were obtained at baseline and weight was updated on each follow-up questionnaire. In a validation study conducted among 115 participants, the correlation coefficient for the means of self-reported weight (176 pounds) and of technician-measured weight (181 pounds) was 0.97 ($p<0.001$), and for self-reported height (64.4 inches) and technician-measured height (64.0 inches) it was 0.93 ($p<0.001$).[22] For women with missing weight in a questionnaire cycle, weight was interpolated as the average of the previous and next reported weight. BMI was calculated as weight in kilograms/height in meters squared. Weight change was calculated as the difference between self-reported weights in 2-year intervals.

Ascertainment of Covariates

Data on age, parity, smoking history, alcohol consumption, number of hours/week in the past year spent in vigorous activity and walking for exercise, and presence of chronic disease, were first obtained in 1995 and updated biennially. Marital status, prior cancer, caregiver responsibilities, and years of education were obtained at baseline in 1995. Energy intake was estimated based on responses in 1995 to a 68-item Block NCI food frequency questionnaire.[23]

Neighborhood SES

Participant residential addresses in 1995, 1997, and 1999 were geocoded. Neighborhood SES was calculated at the level of the block group. Based on factor analysis of 29 block group census variables from the 2000 U.S. census measuring dimensions of education, income, and wealth, six variables were selected to represent neighborhood SES: median household income; median housing value; percentage of households receiving interest, dividends, or net rental income; percentage of adults aged ≥25 years that have completed college; percentage of employed people aged ≥16 years in white-collar occupations; and percentage of families with children not headed by a single woman. Regression coefficients from the factor analysis were used to weight the variables for a combined neighborhood score.

Urban Form Variables

Urban form factors were quantified within the ½-mile network buffer around each participant's residential location using aerial photography, road network files, the 2000 U.S. Census, and transit maps using GIS. The following aspects of urban form were quantified as detailed previously in the *American Journal of Epidemiology*:[21] density, quantified by net housing density (units/acre); interconnectedness of streets, quantified by average block size, intersection density, and ratio of four-way to total intersections; accessibility of public transit, quantified by shortest distance from each participant residence to a subway, train, or ferry stop and length of bus routes within the ½-mile buffer; and percentage of streets with sidewalk coverage (ascertained from aerial photographs).

Factor analysis with varimax rotation was used to combine the urban form variables into one score that represents the urban quality, or "urbanicity," of a neighborhood: Lower scores indicate rural or low-density suburban neighborhoods, and as scores increase, neighborhoods become more urban. One factor was selected based on the proportion of variance explained and examination of the eigenvalues. Street sidewalk coverage and availability of bus routes in the neighborhood were the largest contributors to urbanicity, followed by the measures of street structure and housing density. The urban form score explains 42% of the variability of the seven variables that contribute to it. Regression coefficients from the factor analysis were used to weight the variables for a combined urbanicity score.

Statistical Analysis

Mixed linear regression models were used to calculate the multivariable adjusted least-squares means for changes in body weight across quintiles of the urbanicity score among all women in the analytic cohort (n=17,968). These models accounted for within-person correlation of weight over each 2-year cycle. Regression

Table 1. Characteristics by quintile of urbanicity score, BWHS, 1995

	Urbanicity score quintile				
	Quintile 1 (least urban)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (most urban)
[redacted]					
Age (years)	40.1 (10.9)	39.7 (11.1)	39.5 (11.1)	38.7 (11.1)	37.3 (11.1)
[redacted]					
Energy intake (kcal)	1549 (680)	1573 (671)	1596 (707)	1612 (705)	1619 (693)
[redacted]					
Obese	25.1	28.9	30.7	30.7	29.0
[redacted]					
Marital status: single	25.9	33.0	37.4	40.9	47.5
[redacted]					
<1 hour/week walking for exercise	41.4	45.2	44.1	44.5	42.2
[redacted]					
Current drinker	28.9	28.1	30.4	29.5	30.2

Note: N=17,968
BWHS, Black Women's Health Study

coefficients, representing the mean weight change in each 2-year interval, were multiplied by 3 to obtain mean weight change over the 6-year follow-up period (1995–2001). Results from two models are presented: The basic model was adjusted for age and calendar time, and the multivariate model additionally adjusted for years of education, cigarette smoking, alcohol consumption, marital status, hours/week of vigorous exercise, hours/week of walking for exercise, hours/day of TV viewing, presence of chronic disease, energy intake (kcal/day), parity, history of cancer, study area, and neighborhood SES. All variables were time-varying with the exception of those that were ascertained only once (marital status, caregiver responsibilities, years of education, and energy intake). Thus, for the 30% of women who moved over follow-up, the urbanicity score was updated to reflect changes in their neighborhood urban form.

For the analysis of obesity incidence, the analytic cohort was restricted to women with BMI <30 at baseline (n=12,780). Participants were classified as incident cases of obesity if they attained a BMI of ≥30 during follow-up (n=2228). Participants contributed person-time from baseline in 1995 until the occurrence of obesity, death, loss to follow-up, or end of follow-up, whichever came first. Cox regression models were used to derive incidence rate ratios (IRRs) and 95% CIs for the relationship of the urban form index to obesity incidence. The basic and multivariate models were adjusted for the same variables as in the analysis of change in weight. Missing values were modeled as a separate category.

Separate analyses were conducted among women who had moved during the 6-year follow-up period (n=5357). Those who moved to a neighborhood at least one quintile higher than their previous neighborhood (15% of movers) were characterized as having increased their urbanicity score. Those who moved to a neighborhood at least one quintile lower than their previous neighborhood (17% of movers) decreased their urbanicity score. Women who moved but stayed in the same quintile of the urbanicity score made up the reference group (68% of movers). Least-squares means for changes in body weight in the three categories of movers were calculated. Among movers with BMI <30 at baseline (n=3820), the IRR for obesity for an increase or decrease in urbanicity score relative to the reference group was calculated.

Results

Table 1 shows characteristics of all BWHS participants who lived in the study areas at baseline. In the lower quintiles (least urban), women were older, had lower energy intake and more years of education, and were less likely to be single and current smokers than women in the higher quintiles (most urban). The mean BMI was similar across quintiles of the urbanicity score, although the prevalence of obesity was lowest in the least-urban quintile. The proportion of women who reported low levels of vigorous activity and walking for exercise were similar across quintiles. Associations between the urbanicity score and covariates were similar among women with BMI <30 at baseline.

The mean 6-year weight gain for all participants was 4.79 kg. Table 2 shows the difference in 6-year weight change between the first quintile of urbanicity score (referent) and higher quintiles. In both the basic and multivariable models, women in the higher quintiles gained less weight than did women in the first (referent) quintile, with significant linear trends (Table 2). In the multivariable analysis, mean weight gain for women in the highest

Table 2. Mean difference in 6-year weight gain by quintile of urbanicity score, BWHS, 1995–2001

	Difference in weight gain (kgs; 95% CI)	
Urbanicity score	Model 1[a]	Model 2[b]
[redacted]		
Quintile 2	–0.26 (–0.69, –0.18)	–0.51 (–0.99, –0.02)
[redacted]		
Quintile 4	–0.46 (–0.88, –0.03)	–0.77 (–1.27, –0.26)
[redacted]		
	p_{trend}=**0.002**	p_{trend}=**0.003**

Note: Significant *p*-values are bolded.
[a]Adjusted for age (continuous) and calendar time
[b]Adjusted for age (continuous), calendar time, years of education (<12, 12, 13–15, 16, ≥17); cigarette smoking (current, ex, never); alcohol consumption (current, ex, never); marital status (married, divorced/widowed/separated, single); hours per week of vigorous exercise (<1, 1–2, 3–4, ≥5); hours per week of walking for exercise (<1, 1–2, 3–4, ≥5); hours per day of TV viewing (<1, 1–2, 3–4, ≥5); presence of chronic disease (yes, no); quintiles of energy intake (kcal/day); parity (0, 1, 2, 3, ≥4); history of cancer (yes, no); study area (New York, Chicago, Los Angeles); and neighborhood SES in quintiles.
BWHS, Black Women's Health Study

quintile was 0.79 kg less than for those in the lowest quintile. Obese women gained less weight on average than non-obese women; the inverse relationship between the urbanicity score and weight gain was apparent among women who were normal weight, overweight, and obese at baseline (data not shown).

In the basic model, the incidence of obesity among women of BMI <30 at baseline was not associated with urbanicity score (Table 3). However, after control for potential confounders, the IRR in the highest quintile decreased to 0.83 (95% CI=0.71, 0.97), with a significant trend (p=0.042). The variables vigorous activity and neighborhood SES appeared to play the largest role in the difference between the IRRs derived from Models 1 and 2. There was no association between the urbanicity score and the incidence of overweight (25≤BMI<30) among women of BMI <25 at baseline (data not shown).

Table 4 shows multivariable results for weight change and obesity incidence within strata of study area (New York, Chicago, Los Angeles); age (<40, ≥40 years); and education (≤12, 13–16, ≥16 years). In each of the three geographic areas, women in the higher quintiles of the urbanicity score gained less weight than women in the lower quintiles. Urbanicity score was also inversely associated with incident obesity in each area. The inverse associations of urbanicity score with weight change and incident obesity were stronger among women aged <40 years than among women aged ≥40 years. Urbanicity score was inversely associated with weight change in each stratum of education. Urbanicity score was inversely associated with incident obesity in women with at least 13 years of education. Tests for interaction were significant only for the variation in weight change by study area (p=0.049).

Analysis was conducted among women who moved during follow-up: Women who moved to neighborhoods of higher urbanicity and women who moved to neighborhoods of lower urbanicity were compared to a reference category of women who moved among neighborhoods of similar urbanicity. Six-year weight gain and the risk of obesity did not differ significantly among the three groups (data not shown).

Table 3. Incident obesity by quintile of urbanicity score among women with BMI<30 at baseline, BWHS, 1995–2001

			IRR (95% CI)	
Urbanicity score	Cases	Person-years	Model 1[a]	Model 2[b]
[redacted]				
Quintile 2	434	11,780	1.06 (0.93, 1.20)	0.95 (0.83, 1.08)
[redacted]				
Quintile 4	494	11,636	1.18 (1.04, 1.33)	0.91 (0.79, 1.05)
[redacted]				
			p_{trend}=0.804	p_{trend}=**0.042**

Note: Significant *p*-values are bolded.
[a]Adjusted for age (continuous) and calendar time
[b]Adjusted for age (continuous), calendar time, years of education (<12, 12, 13–15, 16, ≥17); cigarette smoking (current, ex, never); alcohol consumption (current, ex, never); marital status (married, divorced/widowed/separated, single); hours per week of vigorous exercise (<1, 1–2, 3–4, ≥5); hours per week of walking for exercise (<1, 1–2, 3–4, ≥5); hours per day of TV viewing (<1, 1–2, 3–4, ≥5); presence of chronic disease (yes, no); quintiles of energy intake (kcal/day); parity (0, 1, 2, 3, ≥4); history of cancer (yes, no); study area (New York, Chicago, Los Angeles); and neighborhood SES in quintiles
BWHS, Black Women's Health Study; IRR, incidence rate ratio

Table 4. Mean difference in 6-year weight gain and incident obesity by quintile of urbanicity score within strata of study area, age, and education

Urbanicity score, quintiles	6-year weight change (kg) M (95% CI)[a]	Incident obesity among women aged <30 years at baseline: Cases/person-years	Incident obesity among women aged <30 years at baseline: Multivariate IRR[a] (95% CI)
[redacted]			
1	ref	156/4718	ref
[redacted]			
3	–0.44 (–1.23, 0.34)	194/4376	1.03 (0.82, 1.30)
[redacted]			
5	–0.41 (–1.08, 0.27)	380/11,122	0.86 (0.70, 1.06)
[redacted]			
Chicago (*n*=4164 in 1995)			
[redacted]			
2	–1.07 (–2.10, –0.03)	110/2282	0.85 (0.66, 1.10)
[redacted]			
4 and 5[b]	–1.42 (–2.34, –0.50)	208/4228	0.88 (0.69, 1.12)
[redacted]			
Los Angeles (*n*=4117 in 1995)			
[redacted]			
2	–0.67 (–1.50, 0.16)	138/4416	0.99 (0.79, 1.25)
[redacted]			
4 and 5[b]	–0.96 (–1.98, 0.06)	70/1885	0.90 (0.66, 1.23)
[redacted]			
p for interaction	**0.049**	—	0.535
[redacted]			
1	ref	227/5557	ref
[redacted]			
3	–1.08 (–1.84, –0.30)	235/5355	0.96 (0.80, 1.14)
[redacted]			
5	–1.23 (–2.02, –0.44)	247/6533	0.79 (0.64, 0.96)
[redacted]			
Aged ≥40 years (*n*=8059 in 1995)			
[redacted]			
2	–0.52 (–1.14, 0.10)	193/6349	0.98 (0.75, 1.27)
[redacted]			
4	–0.37 (–1.04, 0.31)	213/5807	0.88 (0.70, 1.10)
[redacted]			
p for trend	0.758	—	0.829
[redacted]			

(continued on next page)

Table 4. Mean difference in 6-year weight gain and incident obesity by quintile of urbanicity score within strata of study area, age, and education *(continued)*

Urbanicity score, quintiles	6-year weight change (kg) M (95% CI)[a]	Incident obesity among women aged <30 years at baseline	
		Cases/person-years	Multivariate IRR[a] (95% CI)
[redacted]			
1 and 2[c]	ref	107/2791	ref
[redacted]			
4	–1.00 (–2.26, 0.25)	82/1896	1.03 (0.74, 1.42)
[redacted]			
p for trend	0.264	—	0.934
[redacted]			
1	ref	175/3971	ref
[redacted]			
3	–1.03 (–1.90, –0.17)	175/4151	0.73 (0.58, 0.91)
[redacted]			
5	–1.39 (–2.41, –0.37)	126/3570	0.68 (0.52, 0.88)
[redacted]			
≥16 years of education (*n*=8456 in 1995)			
[redacted]			
2	–0.55 (–1.16, 0.06)	212/6218	0.987 (0.80, 1.19)
[redacted]			
4	–0.78 (–1.43, –0.10)	214/5546	0.87 (0.71, 1.07)
[redacted]			
p for trend	0.098	—	0.177
[redacted]			

Note: Significant *p*-values are bolded.
[a]Adjusted for age (continuous); calendar time; years of education (<12, 12, 13–15, 16, ≥17); cigarette smoking (current, ex, never); alcohol consumption (current, ex, never); marital status (married, divorced/widowed/separated, single); hours per week of vigorous exercise (<1, 1–2, 3–4, ≥5, except in strata of vigorous exercise); hours per week of walking for exercise (<1, 1–2, 3–4, ≥5); hours per day of TV viewing (<1, 1–2, 3–4, ≥5); presence of chronic disease (yes, no); quintiles of energy intake (kcal/day); parity (0, 1, 2, 3, ≥4); history of cancer (yes, no); study area (New York, Chicago, Los Angeles, except in strata of study area); and neighborhood SES in quintiles.
[b]Quintiles 4 and 5 combined due to small numbers in Quintile 5 (17 cases/261 person-years in Chicago and 6 cases/49 person-years in LA)
[c]Quintiles 1 and 2 combined due to small numbers in Quintile 1 (33 cases/1214 person-years)
IRR, incidence rate ratio

Discussion

The present study is the first study to prospectively assess the effect of objectively measured urban form on change in weight and incidence of obesity in African-American women and is the largest to date in terms of numbers of participants and geographic scope. In this population, 6-year weight gain and the risk of incident obesity were lower among women who lived in dense urban neighborhoods compared to those who lived in suburban or rural neighborhoods. The effect of urbanicity on weight change and risk of obesity was more pronounced in women aged <40 years.

Our prospective findings agree with findings on various measures of urbanicity and BMI from cross-sectional studies.[5–7,9–13] The most consistent associations have been with indices of housing or population density and mixed land use. The two largest cross-sectional studies (more than 10,000 participants each) were conducted in Atlanta[10] and New York City.[6] Each study included more than 2000 black subjects and presented race-specific analyses. In the Atlanta study,[10] a continuous index of land-use mix ranging from single use to highly mixed use was most strongly associated with risk of obesity (OR for each quartile increase=0.88, 95% CI=0.84, 0.92). In race-specific analyses, the relationship between the land-use mix and BMI was significant among only white participants. In a similar analysis[24] of the Atlanta data, a different measure of walkability was significantly associated with the BMI among white men only. In the New York City study, associations between BMI and most measures of urbanicity (i.e., population density, land-use mix, public transit availability) were in the expected inverse direction[6] but were stronger in white than in black subjects.[25] A prospective study[26] that used ordinal regression to predict change in BMI over 6 years found no association between objective measures of neighborhood walkability and BMI change, but the study (n=500) had limited statistical power.

In an attempt to isolate the effects on weight change of moving from one type of neighborhood to another in the present study, an analysis was conducted among women who moved, and change in urbanicity was defined as an increase or decrease of at least one quintile of the urbanicity score. There was no appreciable difference in weight change or risk of obesity among the three groups of movers. However, few women moved among areas of drastically different urbanicity: only 1% of movers moved from the lowest to the highest quintile or vice versa, and among the groups who changed their score by at least one quintile, the mean change was little more than one quintile. Further, each of the three compared groups included a range of neighborhood types at baseline. For example, the referent group included women who moved among low-density suburbs or among inner-city neighborhoods. Thus the overlap in neighborhood types may have masked any differences in weight change among movers. In addition, 6 years may be too short a time to discern an effect of change in the environment on weight change.

Three previous studies have assessed weight change by moving status among participants in the NLSY.[4,15,16] Since 1979, the NLSY has periodically enrolled adolescents aged 14–22 years and followed them over time. In the first analysis of NLSY participants enrolled in 1979, a continuous sprawl index was assigned at the county level.[4] Among 262 participants who moved during the follow-up years 1996–2000, there was an association between BMI change and change in the sprawl index such that people who moved to a more-sprawling county gained more weight than those who moved to a less-sprawling county.[4] In another analysis[15] of the 1979 NLSY cohort, sprawl was calculated for a 2-mile radius around participant residences during follow-up years 1988–1994. Among the approximately 5400 people who moved between 1988 and 1994, sprawl had no effect on change in BMI during the time period. In the third analysis[16] of a new NLSY cohort enrolled in 1997, there was no association between county sprawl and 6-year change in BMI among 2427 people who moved among counties. In all three analyses, sprawl was a continuous variable and it is unclear how many people moved from low- to high-sprawl areas and vice versa.

Strengths of the current study include assessment of African-American women who have been understudied in regard to the built environment, the prospective analyses, the large size of the cohort, the inclusion of three major metropolitan areas, the detailed assessment of urbanicity at the level of the residential address, and control for a range of individual- and neighborhood-level confounders.

Study limitations include the use of self-reported weight, although a validation study showed acceptable accuracy. Accuracy of self-report has been related to age,[27] but in the present study change in reporting accuracy over time is unlikely to have been associated with urban form. Data on land use or distance to specific destinations, which other studies[6,9–13] have found to be important, were not available. Census data from the year 2000 were assigned to locations in earlier years, although it is not likely that values changed greatly between 1995 and 2000. The BWHS includes few women with less than a high school education, so results may not be generalizable to this group. Finally, although the analyses were prospective and were adjusted for a range of variables known to influence weight gain, residual confounding due to selection bias may have played some role in the results.

In summary, in prospective analyses urbanicity was inversely associated with weight gain and risk of obesity. This strengthens the evidence that living in denser urban areas is associated with less weight gain and obesity than living in suburban or rural areas. Policies that encourage more dense and urban residential development may have a positive role to play in addressing the obesity epidemic. Residents of rural and suburban areas should be aware that such low-density environments may contribute to weight gain, and efforts to maintain a healthy weight may be needed.

This work was supported by a grant from the National Heart, Lung, and Blood Institute (HL08139). Study infrastructure, data collection, and follow-up of study participants were supported by the National Cancer Institute (CA58420). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung, and Blood Institute, the National Cancer Institute, or the NIH.

No financial disclosures were reported by the authors of this paper.

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