Original Article
EPIDEMIOLOGY/GENETICS

Obesity

Neighborhood Health-Promoting Resources and Obesity Risk (the Multi-Ethnic Study of Atherosclerosis)

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Objective: While behavioral change is necessary to reverse the obesity epidemic, it can be difficult to achieve and sustain in unsupportive residential environments. This study hypothesized that environmental resources supporting walking and a healthy diet are associated with reduced obesity incidence.
Design and Methods: Data came from 4,008 adults aged 45-84 at baseline who participated in a neighborhood ancillary study of the Multi-Ethnic Study of Atherosclerosis. Participants were enrolled at six study sites at baseline (2000-2002) and neighborhood scales were derived from a supplementary survey that asked community residents to rate availability of healthy foods and walking environments for a 1-mile buffer area. Obesity was defined as BMI $\geq$ 30 kg/m^2. Associations between incident obesity and neighborhood exposure were examined using proportional hazards and generalized linear regression.
Results: Among 4,008 nonobese participants, 406 new obesity cases occurred during 5 years of follow-up. Neighborhood healthy food environment was associated with 10% lower obesity incidence per s.d. increase in neighborhood score. The association persisted after adjustment for baseline BMI and individual-level covariates (hazard ratio (HR) 0.88, 95% confidence interval (CI): 0.79, 0.97), and for correlated features of the walking environment but CIs widened to include the null (HR 0.89, 95% CI: 0.77, 1.03). Associations between neighborhood walking environment and lower obesity were weaker and did not persist after adjustment for correlated neighborhood healthy eating amenities (HR 0.98, 95% CI: 0.84, 1.15).
Conclusions: Altering the residential environment so that healthier behaviors and lifestyles can be easily chosen may be a precondition for sustaining existing healthy behaviors and for adopting new healthy behaviors.

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Introduction

Adult obesity is associated with numerous morbidities including higher risk of type 2 diabetes, hypertension, and heart disease (1,2). In the United States, unhealthy weight gain is common among all ages, including older adults who are past mid-life (3). To decrease the prevalence of obesity, a multilevel, multifaceted public health approach is needed that includes altering external stimuli that encourage normative behaviors of unhealthy eating and physical inactivity (4).

Recent interest in the effects of the built environment on health behaviors and health outcomes is motivated by potential population health impacts from interventions or policies that affect the built environment. Cross-sectional studies have investigated associations of the local food and physical activity (PA) environments with BMI. The presence of supermarkets near one's residence has generally been found to be associated with lower prevalence of BMI or obesity (5,6,7). Cross-sectional time series has also found associations between increases in neighborhood food stores offering predominantly unhealthy foods and increases in obesity (8). To date, evidence of cross-sectional associations between residential neighborhood "walkability"—neighborhoods thought to be highly walkable—with adult PA and obesity is mixed (9), but has generally pointed toward an association between low walkability and overweight/obesity (10). This is likely due at least in part to associations between walkable neighborhoods and energy expenditure via transportation-related PA and overall adult PA (11,12). A recent cross-sectional analysis by Mujahid *et al.* (13) using data from the Multi-Ethnic Study of Atherosclerosis (MESA) linked to a community

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survey that rated environments on the suitability for walkability and availability of healthy foods found a negative relationship with adult BMI independent of age, race/ethnicity, education, and income. A number of other studies have examined the potential contribution of neighborhood environment to adult obesity. However, causal inference from all of the aforementioned cross-sectional analyses is limited because of the inability to determine whether weight gain preceded the neighborhood exposure.

Expert reviews have called for longitudinal studies examining neighborhood characteristics and incident obesity because they would strengthen inferences regarding causal effects of these environments (14). To date, longitudinal studies have primarily examined associations between neighborhood socioeconomic status (SES) and weight gain or incident obesity and generally found neighborhood deprivation associated with obesity (15-17). One study went beyond neighborhood SES to examine whether specific features of neighborhoods relate to BMI change. Berry *et al.* (18) examined whether walkability (using a Geographic Information Systems derived walkability index plus a self-perceived built environment index derived from a 10-item questionnaire that included road traffic) and neighborhood SES were associated with BMI change after 6 years; only neighborhood SES and participant-reported road traffic showed the expected association. Generalizability is a limitation of the longitudinal studies to date, since these studies were conducted only among subgroups and in some cases used self-reported weight (16,17) and/or were conducted outside the United States (15,18) where neighborhood environments are likely quite different.

To date, no study has examined associations between specific neighborhood features, namely walkability and healthy food resources, and incident obesity. We used longitudinal data from a large multiethnic cohort of middle-aged and older adults to examine associations between neighborhood environments and incidence of obesity (where the neighborhood environment is characterized using informant reports of the neighborhood). We hypothesized that neighborhood suitability for walking and buying healthy foods reduces obesity risk.

Methods and Procedures

Person-level data

Person-level data came from MESA, a longitudinal study of risk factors for atherosclerosis (19), which recruited participants aged 45-84 years from six field centers (New York and Bronx counties, New York; Baltimore City and County, Maryland; Forsyth County, North Carolina; Chicago, Illinois; St. Paul, Minnesota; and Los Angeles, California). A variety of population-based approaches were used for recruiting, including commercial lists of area residents and random digit dialing (for more details see www.mesa-nhlbi.org/ and Bild (19)). Only persons free from clinical cardiovascular disease at baseline were eligible. Data were used from the baseline exam (collected 2000-2002) and three follow-up exams, which occurred ~1.6, 3.1, and 4.8 years later (last data collection was May 2007); participant retention rates were 94%, 89%, and 86%, respectively.

All participants provided written informed consent and the study was approved by the Institutional Review Boards at all participating institutions.

Measurement of obesity and covariates

BMI was calculated from measured weight and height at physical examinations at each follow-up visit (weight/height in kg/m^2). Obesity was defined as BMI $\geq$30 kg/m^2 the first time a person's BMI reached this threshold regardless of subsequent BMI. Covariates were measured at baseline via study questionnaire. Socio-demographic characteristics included age, sex, self-reported race/ethnicity, acculturation index (immigrant status, years in the United States, language spoken at home (20)), per capita household income, household assets (21) (owns home, investments, property other than primary home), and education. Other covariates include cigarette smoking status, PA, and diet (see Table 1 for categorization scheme).

PA during a typical week was assessed using a detailed, standardized, semi-quantitative questionnaire adapted from the Cross-Cultural Activity Participation Study (19,22) and total metabolic equivalent task minutes were estimated for a combination of walking, moderate and vigorous intensity sports, and conditioning activities (as previously reported (19,23)). From this, hours per day of PA was derived; and to improve interpretability of this variable, the variable was classified into tertiles in regression models.

Dietary measurements, compiled from a food frequency questionnaire (24), were used to derive an index of a healthy diet, "the alternate healthy eating index (25)", which has been used in previous work (26) because it strongly correlates with major chronic disease and cardiovascular disease risk (25). The index ranges from 2.5 to 87.5, and high scores indicate a better quality diet (high intake of fruits, vegetables, soy, protein, white meat, cereal fiber, polyunsaturated fat, and multivitamins and lower intake of alcohol, saturated fat, and red meat). All data were collected at follow-up exams except for dietary measures (see Supplementary Table S1 online for details).

Neighborhood data

During 2003-2005, MESA participants were enrolled in an ancillary study, the MESA Neighborhood Study (see refs for details (27,28)). Residents were asked to refer to the area in about a 20-minute walk or about a mile from their home and they provided a one-time report on a number of neighborhood-level domains potentially related to cardiovascular disease. Two scales were used in this study: one that assessed the walking environment and another that assessed the availability of healthy foods. Items were derived from published work whenever possible (27,28). Residents were asked if it was "pleasant" and "easy" to walk to places in their neighborhood, and if a large selection of fruits, vegetables, and low fat foods was available nearby for purchase (see Supplementary Table S2 online). Each item within a scale had a 5-point response option and within-scale items were averaged. Scale internal consistency was acceptably high for walking environment and availability of healthy foods (0.61 and 0.90, respectively) (29). Responses for residents living within 1 mile of the MESA referent person were averaged to create a measure of the neighborhood characteristics for each MESA residential address at baseline (henceforth referred to as *informant reports of the neighborhood*). Averaged informant reports of the neighborhood did not include the MESA respondent's report of their own neighborhood to avoid spurious associations that can result when neighborhood information and behaviors are self-reported by the same subjects (30). One mile was used to proxy MESA participants' neighborhoods. The 1-mile buffer corresponded to the neighborhood survey, which asked respondents to report on the area in about a 20-minute walk or about a mile from their home and has frequently been used in federal government definitions of access to services, thus is relevant to policy (31).

TABLE 1 Sample characteristics before and after exclusion of obesity cases at baseline and sample characteristics by obesity status at follow-up. Multi-Ethnic Study of Atherosclerosis, 2000-2007

	Baseline		Obese at follow-up (≥30 kg/m²)	
	Before exclusion	After exclusion[a]	No	Yes
N	6,191	4,008	3,602	406
Age, baseline (mean (s.d.) years)	61.91 ± 10.14	62.35 ± 10.33	62.65 ± 10.36	59.67 ± 9.66
Sex (%)				
Women	52.4	49.7	49.9	48.3
Men	47.6	50.3	50.1	51.7
Race/ethnicity (%)				
White	39.3	42.1	42.2	41.4
Chinese	11.8	16.7	18.1	4.7
African American	27.4	21.8	21.2	26.3
Hispanic	21.6	19.4	18.5	27.6
Acculturation index (%)[b]				
Low	18.2	21.6	22.3	15.0
Medium	9.3	9.1	9.1	9.3
High/US-born	66.4	62.9	62.2	69.5
Per capita family income, per $10,000 (mean, s.d.)	2.65 ± 2.07	2.72 ± 2.16	2.73 ± 2.17	2.66 ± 2.08
Assets (%)[c]				
Few	22.2	21.6	21.4	23.4
Education (mean, s.d.)	13.21 ± 3.98	13.34 ± 4.05	13.40 ± 4.04	12.79 ± 4.17
Smoking status (%)				
Never	48.4	49.8	50.4	43.8
Former	38.7	37.2	36.9	39.9
Current	12.9	13	12.7	16.3
Healthy eating index (higher is better) (mean, s.d.)[d]	57.17 ± 11.90	57.62 ± 11.65	57.82 ± 11.63	55.84 ± 11.67
Physical activity hours per day (mean, s.d.)[e]	3.77 ± 5.68	4.08 ± 6.03	4.05 ± 5.97	4.32 ± 6.50
BMI at baseline, kg/m² (mean, s.d.)	28.31 ± 5.42	25.39 ± 2.85	25.01 ± 2.73	28.80 ± 1.14
Overweight (BMI 25–<30), at baseline (%)	71.2	57.8	53	98
Obese (BMI ≥30, %)	32.0	0	89.9	10.1
Walking environment (mean, s.d.)[f]	3.85 ± 0.31	3.87 ± 0.32	3.87 ± 0.32	3.82 ± 0.29
Healthy foods environment (mean, s.d.)[f]	3.47 ± 0.60	3.51 ± 0.60	3.52 ± 0.59	3.36 ± 0.63

[a]Excluded persons obese at baseline (32%, n = 1,976), persons not obese at baseline but with address errors (n = 97); missing neighborhood-level exposures (n = 60); or key covariates (n = 50). The samples were statistically significantly different $P < 0.05$ for all except family income, assets, education, smoking, and diet/healthy eating index.
[b]Acculturation index was compiled from immigrant status, years in the United States, and language spoken at home; the index ranged 0–5. For this table, low = 0–1, medium = 2–4, and high = 5.
[c]Assets was derived from owns home, investments, property other than primary home.
[d]A healthy eating index (McCullough (25)) was derived from a frequency questionnaire; see text for details.
[e]Physical activity metabolic equivalent task-hours for walking, moderate and vigorous intensity sports, and conditioning activities. Median physical activity hours per day are 2.0, 2.3, 2.3, 2.1, respectively for the four columns.
[f]Neighborhood informant reports on neighborhood availability of the walking and healthy foods environment; see Methods for details.

Participants included in study

Of the 6,814 persons enrolled at baseline, 6,191 participated in the ancillary study (19). Analyses performed for incident obesity excluded persons obese at baseline (32%, n = 1,976). Additional persons were excluded due to address errors (n = 97), missing neighborhood-level exposures (n = 60), or key covariates (n = 50).

(See Results for comparison of included vs. excluded.) A total of 4,008 participants were included in the descriptive analyses and initial series of regression models. An additional 299 persons did not complete the dietary questionnaire and thus were further excluded when controlling for diet; excluding these observations did not affect the estimates of interest but these observations were kept in the initial series of models in order to preserve statistical power.

Statistical analyses

We first examined the distribution of individual-level variables for persons who did and did not become obese during follow-up; and the distribution of neighborhood variables across the person-level variables. Poisson regression was used to estimate age-adjusted incidence rates for tertiles of neighborhood exposures by sex (32,33). Pooled results are shown for all subsequent analyses because patterning of rates across neighborhood exposures were roughly similar for women and men; in regression models statistical significance for sex interactions was $P > 0.2$, and in adjusted models stratification by sex showed similarity of neighborhood effects.

Proportional hazards regression was used to derive hazards ratios for associations of informant reports of the neighborhood with incident obesity, after adjustment for age, sex, race/ethnicity, acculturation to United States, income, household assets, education, cigarette smoking status, diet, and PA. When variables were assessed during interim years (see Supplementary Table S1 online) they were specified as time-varying in the regression models. Hazard ratios (HRs) were examined before and after baseline BMI was included, and before and after adjustment for the other neighborhood measure (informant reports of neighborhood food and walking environments were examined adjusted for each other). Adjustment for baseline BMI was necessary due to unequal population distributions of baseline BMI across neighborhood environments. All models included baseline age, age squared, race/ethnicity, acculturation score, income, assets, education, education squared, and cigarette smoking status (2-13). Squared terms were used after diagnosing nonlinearity of adjusted effects between covariates and the response variable. Multicollinearity diagnostics indicated acceptable variance inflation factors when both neighborhood scores were in the regression model, variance inflation factors <3. To compare associations of neighborhood variables that have different units, estimates shown correspond to differences in 1 s.d. unit (translating to differences of 0.32 in the walking scale (range 2.00-4.91), and 0.60 in the healthy foods scale (range 1.00-5.00)). Because some respondents reside near each other, a robust covariance matrix estimator (sandwich estimator) was used for all regression models to account for clustering of observations within tracts (34,35).

Interactions

Based on prior literature, we tested whether the following baseline variables modified the association between informant reports of the neighborhood and incident obesity: income, race/ethnicity, education, study site, overweight at baseline, car ownership (which may suggest the degree to which households may be constrained to their neighborhood), and dose of neighborhood exposure (years of residence in the neighborhood and whether participants moved from their baseline address).

Results

Descriptive

At baseline, of the 6,191 total MESA participants, 71% of the sample was overweight and 32% were obese (Table 1). Persons obese at baseline were excluded from the incident analyses. Differences between included and excluded participants were statistically significant for a number of covariates (see Table 1 footnote), but substantively important differences were only observed for race–ethnic differences (one-third to one-half of African American and Hispanic women were excluded due to baseline obesity). Compared with the total population, the 4,008 participants not obese at baseline included in the analyses were lower percent African American and had a more favorable PA profile. Among those overweight at baseline, 18% became obese over the follow-up, compared with only 2% among those with normal weight at baseline.

Persons with higher income, education, and better diet and PA profiles tended to live in areas with more favorable neighborhood informant reports of suitability for walking (test for trend <0.001) and buying healthy foods (test for trend <0.001), although the gradient was more apparent for healthy foods (Table 2). White persons lived in areas with the highest food environment score, while Chinese and Hispanics lived in areas with the highest walking environment score.

More favorable reports on neighborhood access to healthy foods were associated with a graded reduction in age-adjusted obesity incidence rates with the association being more marked for healthy food environment (Figure 1). Incidence patterns were roughly similar for men and women and P values for sex by environment interactions in adjusted models were $P > 0.1$ for healthy eating environment on obesity and $P > 0.2$ for all other models. Because sex stratification did not enhance the substantive findings and reduced power, subsequent results are reported for the pooled sample. Pooled across sex, among persons living in the worst, intermediate, and best neighborhoods for healthy foods, the per 1,000 person–years obesity incidence was 31.4, 20.4, and 17.8, respectively. Obesity incidence was the lowest for those living in better walking environments, but the gradient was less clear.

Adjusted models: incidence of obesity

More favorable reports on neighborhood access to healthy foods were associated with lower obesity incidence throughout most phases of adjustment. Neighborhood resources that support walking had a weaker association, and confidence intervals (CI) included the null in all models except for the model that did not adjust for baseline BMI or healthy food environment. Table 3, column A shows the association of neighborhood score with incident obesity. Adjusting for age, sex, race/ethnicity, acculturation score, SES (family income, assets), and cigarette smoking, obesity incidence during follow-up was 18% lower for each 1 s.d. increase in favorable food environment (model 1 A, HR 0.82, 95% CI: 0.75, 0.90) and 11% lower for each s.d. increase in favorable walking environment (model 1 A, HR 0.89, CI: 0.81, 0.98). Additional adjustment for individual-level exercise and diet did not affect the magnitude of the association substantially, although there was a slight attenuation (model 2 A). Table 3, column B shows the estimated association after accounting for baseline BMI: the association was slightly weaker but persisted (model 2 B, HR 0.88, 95% CI: 0.79, 0.97 for food environment and HR 0.90, 95% CI: 0.81, 1.00 for walking

TABLE 2 Neighborhood characteristics by person-level characteristics. Multi-Ethnic Study of Atherosclerosis, 2000–2007, $n = 4{,}008$

		Neighborhood scales	
		Healthy foods environment	Walking environment
		Mean ± s.d.	Mean ± s.d.
Demographics			
Age, baseline (years)	45–<55	3.87 ± 0.31	3.51 ± 0.57
	55–<65	3.88 ± 0.32	3.51 ± 0.60
	65–<75	3.86 ± 0.32	3.49 ± 0.63
	75+	3.88 ± 0.32	3.57 ± 0.57
Sex	Women	3.88 ± 0.32	3.53 ± 0.61
Race/ethnicity	White	3.96 ± 0.37	3.48 ± 0.72
	Chinese	3.77 ± 0.25	3.66 ± 0.28
	African American	3.81 ± 0.26	3.33 ± 0.62
	Hispanic	3.81 ± 0.23	3.64 ± 0.39
Acculturation index	Low	3.76 ± 0.22	3.67 ± 0.29
	Medium	3.89 ± 0.29	3.73 ± 0.43
	High/US-born	3.90 ± 0.34	3.41 ± 0.68
Socioeconomic status			
Per capita family income	Lowest tertile	3.76 ± 0.23	3.53 ± 0.42
	Middle	3.84 ± 0.28	3.43 ± 0.59
	Highest tertile	3.98 ± 0.37	3.56 ± 0.71
Assets	Few assets	3.78 ± 0.23	3.61 ± 0.40
	High assets	3.89 ± 0.33	3.48 ± 0.64
Education	<High school	3.76 ± 0.21	3.54 ± 0.42
	High school	3.78 ± 0.27	3.41 ± 0.55
	Some college	3.85 ± 0.31	3.46 ± 0.58
	BA or more	3.96 ± 0.35	3.58 ± 0.67
Other risk factors			
Smoking	Never	3.85 ± 0.31	3.51 ± 0.59
	Former	3.90 ± 0.33	3.52 ± 0.63
	Current	3.85 ± 0.30	3.48 ± 0.56
Healthy eating index (higher is better)	Low tertile	3.83 ± 0.30	3.45 ± 0.58
	Middle tertile	3.87 ± 0.32	3.52 ± 0.59
	High tertile	3.90 ± 0.34	3.55 ± 0.62
Physical activity hours per day	Low tertile	3.79 ± 0.29	3.46 ± 0.55
	Middle tertile	3.87 ± 0.31	3.51 ± 0.59
	High tertile	3.93 ± 0.33	3.56 ± 0.64
BMI, kg/m^2	<25	3.89 ± 0.33	3.57 ± 0.60
	25–<30, overweight	3.85 ± 0.31	3.47 ± 0.59

environment). After further adjustment for correlated neighborhood features, CIs widened to include the null for food environment and the association for walking environment completely disappeared (model 4 B, HR 0.89, 95% CI: 0.77, 1.03 for healthy foods, HR 0.98, 95% CI: 0.84, 1.15 for walking environment).

Heterogeneity of associations

Heterogeneity of associations was examined, adjusted for age, sex, income, assets, education, race/ethnicity, acculturation score, cigarette smoking status, exercise, diet, and baseline BMI. Heterogeneity was statistically significant for some factors but on a substantive level, differences between strata were minor (see Supplementary Table S3 online). Neighborhood food environment was most protective among persons not overweight at baseline. Neighborhood PA environment was most protective among persons with lower income and persons who lived in the neighborhood <15 years (the median number of years). Although associations of neighborhood food and PA environment with obesity differed by education, there was no clear pattern. No statistically significant differences were found by race/ethnicity, enrollment study site, car ownership, and moved during follow-up ($P \geq 0.05$, not shown). Twenty percent of participants moved from their neighborhood at some point during the follow-up period. The new neighborhoods shared similar characteristics to their baseline neighborhood (Pearson correlations between pre- and post-move neighborhood scores was 0.60, not shown) and the neighborhood association with obesity incidence was not statistically different between movers and nonmovers.

Discussion

In this longitudinal study of aging adults, more favorable neighborhood informant reports of access to healthy foods were associated with a 12% lower obesity incidence even after adjustment for numerous risk factors for obesity and for baseline BMI (HR 0.88, 95% CI: 0.79, 0.97). The magnitude of the association persisted after adjustment for correlated features of the walking environment, although CIs widened to include the null (HR 0.89, 95% CI: 0.77, 1.03). Similarly, favorable neighborhood informant reports regarding the suitability of the walking environment was associated with 10%

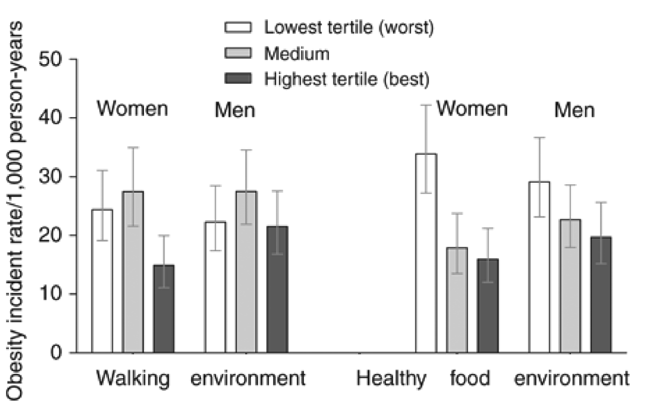

FIGURE 1 Obesity incidence rates per 1,000 person–years (with 95% confidence intervals) across tertiles of neighborhood scores; the Multi-Ethnic Study of Atherosclerosis, 2000–2007.

TABLE 3 Adjusted hazard ratios (HR) with 95% confidence intervals (CIs) of becoming obese corresponding to 1 s.d. increase in favorable neighborhood environment; the Multi-Ethnic Study of Atherosclerosis, 2000–2007

		Unadjusted for baseline BMI[a]			Adjusted for baseline BMI[a]		
Model no.	Covariate adjustment	HR	95% CI	*P* value	HR	95% CI	*P* value
Healthy food environment							
Model 1	Age, sex, income, assets, education, race/ethnicity, acculturation score, and cigarette smoking status	0.82	(0.75, 0.90)	<0.001	0.87	(0.79, 0.97)	0.009
Model 2	+Exercise and diet	0.84	(0.76, 0.92)	<0.001	0.88	(0.79, 0.97)	0.013
Model 3	Age, sex, income, assets, education, race/ethnicity, acculturation score, and cigarette smoking status, neighborhood walking environment	0.79	(0.70, 0.90)	<0.001	0.87	(0.75, 1.00)	0.054
Model 4	+Exercise and diet	0.82	(0.72, 0.94)	0.005	0.89	(0.77, 1.03)	0.122
Walking environment							
Model 1	Age, sex, income, assets, education, race/ethnicity, acculturation score, and cigarette smoking status	0.89	(0.81, 0.98)	0.021	0.91	(0.82, 1.01)	0.076
Model 2	+Exercise and diet	0.90	(0.81, 0.99)	0.039	0.90	(0.81, 1.00)	0.060
Model 3	Age, sex, income, assets, education, race/ethnicity, acculturation score, and cigarette smoking status, neighborhood healthy food environment	1.05	(0.91, 1.21)	0.485	1.01	(0.87, 1.16)	0.914
Model 4	+Exercise and diet	1.03	(0.89, 1.19)	0.706	0.98	(0.84, 1.15)	0.794

[a]Estimates shown correspond to differences in 1 s.d. unit which translates to differences of 0.32 in the walking environment scale (range 2.00–4.91), and 0.60 in the healthy food environment scale (range 1.00–5.00). Models 1 and 3 include 4,008 participants; models 2 and 4 include 3,709 participants (299 were missing dietary information).

lower obesity incidence after adjustment for risk factors and baseline BMI (HR 0.90, 95% CI: 0.81, 1.00), although the association was not independent of correlated neighborhood healthy eating amenities.

There is a lack of longitudinal work to compare with our results. Prior cross-sectional studies estimating the likelihood of obesity with increases in favorable neighborhood physical environments anchored reasonably well to the baseline results from this study, thus lending confidence in estimates reported here (6,36-38). One of the challenges for studying the determinants of new cases of obesity in the United States is the high baseline prevalence of adult overweight and obese. One-third of the cohort was excluded due to being obese at baseline. This may limit generalizability of the results, particularly generalizability to African American and Hispanic women since one-third to half of these persons were excluded due to baseline obesity. Nevertheless, the study was able to detect associations between protective features of the environment and obesity (BMI $\geq$ 30 kg/m^2) which persisted after conditioning on baseline weight (BMI). The high prevalence of baseline obesity prevented analyses of incidence of overweight (BMI 25 – $<$ 30 kg/m^2) since 58% of the sample would have been excluded. Incidence of severe obesity (BMI $\geq$ 35 kg/m^2), which has been most strongly associated with excess mortality (39) also could not be examined due to low incidence during 5 years of follow-up.

Researchers have used at least four methods to assess neighborhood walkability and availability of high-quality healthy foods: survey-derived participant perceptions and community perceptions, ground audits, and commercial listings or other remotely collected Geographic Information Systems data (for reviews of these methods see refs 40-42). Using diverse assessment methods, constructs that assess neighborhood walkability and availability of high-quality healthy foods have been shown to have roughly similar rankings (excluding safety from crime), but they do not perfectly concur; this is likely because they measure different aspects of the same construct (43-45). Due to the expense of ground audits, almost all studies have used survey-derived participant perceptions or remotely collected Geographic Information Systems data. Resident surveys can capture dimensions that are difficult if not impossible to measure using commercial listings or other remotely collected GIS data: access, quality, and usability of resources. A strength of the current study is that neighborhood amenities were assessed by persons other than the MESA referent person thus results were not likely systematically biased by the correlation between self-perceived community-level amenities and self-reported behaviors (30).

The current study asked community residents whether there was a large selection of fresh fruits and vegetables and low fat products in their neighborhood. These do not capture all dimensions of healthy food availability, but have frequently been used as markers to proxy availability of healthy options in retail environments (46). A 1-mile area was used to crudely approximate participant exposure to this measure. This distance has frequently used in federal government definitions of access to services, thus is relevant to policy (31). Studies have generally showed low sensitivity to use of 1-mile or larger area nevertheless it is plausible that measurement error in the relevant geographic scale for accessing healthy food and walkable neighborhoods reduced our ability to detect a stronger association (47). In addition, models that included both food and walking environment variables did not consistently detect an association with obesity independent of the other neighborhood factor likely in part due to the collinearity between these two measures, which made it difficult to detect independent associations with incident obesity.

Most participants resided for a long period (median of 17 years) in their neighborhood; thus, to the extent that neighborhood environments remain stable over time, participants may have had long-term exposure to their neighborhood's resources. The neighborhood association with obesity incidence was not statistically different between movers and nonmovers likely due to participants relocating to neighborhoods that shared similar characteristics to their baseline neighborhood (48) (as indicated by high correlations between pre- and postmove neighborhood scores).

This is the first study to examine neighborhood resources for healthy eating and walkability with incident obesity in a large multi-site US population-based, multiethnic sample. Results suggest that a relatively modest improvement in neighborhood environments (equivalent to a 1 s.d. change in our sample) could reduce obesity incidence by 10%. Having healthy foods easily available and designing walkable residential environments will not reverse the obesity epidemic by themselves but may play an important role in combination with other facilitators of healthy behaviors. There are no easy answers to halting the obesity epidemic; prevention strategies will need to be adopted in most facets of daily life. However, suitable environments are likely to be a precondition for sustaining existing healthy behaviors and for adopting new healthy behaviors.O

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