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# You Are Where You Shop

## Grocery Store Locations, Weight, and Neighborhoods

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**Background:** Residents in poor neighborhoods have higher body mass index (BMI) and eat less healthfully. One possible reason might be the quality of available foods in their area. Location of grocery stores where individuals shop and its association with BMI were examined.

**Methods:** The 2000 U.S. Census data were linked with the Los Angeles Family and Neighborhood Study (L.A.FANS) database, which consists of 2620 adults sampled from 65 neighborhoods in Los Angeles County between 2000 and 2002. In 2005, multilevel linear regressions were used to estimate the associations between BMI and socioeconomic characteristics of grocery store locations after adjustment for individual-level factors and socioeconomic characteristics of residential neighborhoods.

**Results:** Individuals have higher BMI if they reside in disadvantaged areas and in areas where the average person frequents grocery stores located in more disadvantaged neighborhoods. Those who own cars and travel farther to their grocery stores also have higher BMI. When controlling for grocery store census tract socioeconomic status (SES), the association between residential census tract SES and BMI becomes stronger.

**Conclusions:** Where people shop for groceries and distance traveled to grocery stores are independently associated with BMI. Exposure to grocery store mediates and suppresses the association of residential neighborhoods with BMI and could explain why previous studies may not have found robust associations between residential neighborhood predictors and BMI.  
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### Introduction

Obesity is associated with diabetes, high blood pressure, high cholesterol, arthritis, and poor health status,<sup>1</sup> and accounted for 9.1% of the total annual medical expenditures in the United States in 1998.<sup>2</sup> As the epidemic of obesity and its attendant consequences are common throughout the United States, there are disparities in its prevalence: African Americans, Latinos, and those who live in disadvantaged areas are more likely to be obese.<sup>3–6</sup> Understanding the mechanism that underlies these disparities may hold clues to solving a rising epidemic that puts the health of all Americans at risk and guarantees the continued rise in U.S. medical expenditures.<sup>7</sup> Undoubtedly, many of these mechanisms operate at the

level of individual lifestyle choices,<sup>8,9</sup> but there is increasing evidence that neighborhood resources condition those choices.<sup>10–15</sup>

Previous studies have found that blacks, Latinos, and disadvantaged groups live in areas that have inadequate access to healthy foods that directly affect their dietary quality and health. In 1998, 40% of the 939 diabetic adults surveyed in East Harlem, New York, a predominantly Latino area, stated that they did not follow the recommended dietary guidelines because foods necessary to maintain a diabetic diet were less available and more expensive in their neighborhood grocery stores.<sup>10</sup> In this study, Horowitz et al.<sup>10</sup> found that only 18% of East Harlem bodegas (neighborhood stores), compared with 58% of Upper East Side bodegas, carried at least one of the following recommended diabetic diet food items: diet soda, 1% fat or fat-free milk, high-fiber bread, fresh fruits, fresh green vegetables, or tomatoes. In Los Angeles, supermarkets and neighborhood grocery stores in lower-socioeconomic status (SES) African-American communities were found to have lower quality and less variety of fresh fruits and vegetables as well as fewer low-fat and healthy food products compared to wealthier areas with fewer African-American residents.<sup>11</sup>

Supermarkets have been shown to be fewer in number<sup>12</sup> and farther in distance<sup>13</sup> in predominantly black neighborhoods compared to white neighborhoods.

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Food items at supermarkets consistently were lower in price compared to items found in smaller stores,<sup>16</sup> and supermarkets had more than twice the average number of “heart-healthy” foods compared to smaller neighborhood grocery stores.<sup>17</sup> The number and proximity of supermarkets may play an important role in health outcomes because additional supermarkets within the residential census tract were shown to increase fruit and vegetable intake in African Americans,<sup>14</sup> and proximity to supermarket was shown to improve the dietary quality of pregnant women.<sup>15</sup>

Given these patterns of food availability, one would expect that residents of poor neighborhoods would have higher body mass indexes (BMIs). Yet, residential disadvantage has had inconsistent associations to individual BMI. At times, it has shown modest association to BMI,<sup>4,6</sup> being overweight<sup>3</sup> or obese,<sup>5</sup> while at other times, no association to either BMI<sup>4</sup> or obesity<sup>18</sup> was found. One explanation for this seeming inconsistency is that none of these studies accounted for the shopping habits of its residents. In a previous paper, exposure to environments, besides where one lives, was shown to modify the impact of the residential neighborhood on health.<sup>19</sup> Using the Los Angeles Family and Neighborhood Study (L.A.FANS) database linked to U.S. Census data, multilevel models were used to analyze the impact on individual BMI of where people shop for groceries, controlling for other individual and neighborhood characteristics.

## Materials and Methods

### Sample

Data from the 2000–2002 L.A.FANS and the 2000 decennial U.S. Census file were used. All analyses were performed in 2005. L.A.FANS is a longitudinal study based on a stratified random sample of 65 neighborhoods (census tracts from the 1990 Census) in Los Angeles County. Poor neighborhoods were over-sampled. An average of 41 households in each neighborhood were randomly selected and interviewed for the first wave. A household survey asked adults about household economic status, education, employment, income, marital history, and neighborhoods of residence, as well as about locations of where they worked, worshipped, obtained medical care, shopped for groceries, and went for entertainment.<sup>20</sup> Because of the relationship of grocery stores to food and the relationship of food to obesity, grocery store locations were the focus of the study. In the analyses presented here, respondents for whom income ( $n=39$ ), BMI ( $n=310$ ), and grocery store location ( $n=286$ ) were missing, and for whom BMI was  $>47$  ( $n=9$ ) were eliminated; the final sample size was 2144 from the original sample size of 2620.

Respondents missing grocery store information were significantly ( $p<0.05$ ) less likely to be employed (56% vs 67.5%) and to reside in a very-low-SES area (33% vs 39%). Respondents missing BMI information had lower mean income (\$37,000 vs \$52,000), were significantly ( $p<0.05$ ) less likely to be employed (54% vs 68%), college educated (12% vs 20%), white (19% vs 26%), and to own a car (65% vs 76%).

Residential neighborhoods and grocery store locations were identified at the census-tract level. The L.A.FANS sampling strategy was based on census tract boundaries identified from the 1990 Census. Because the survey took place in 2000, data were extracted from the 2000 decennial census file, weighted to reflect the 1990 census tract boundaries, and then merged with the individual-level records from the L.A.FANS database.

### Measures

**Dependent variable.** Respondents were asked to provide their height and weight; from this information each respondent's BMI was calculated. BMI was analyzed as a continuous outcome.

**Residential neighborhood disadvantage.** Four summary statistics of census tracts in Los Angeles County were each standardized and then combined to create a neighborhood “disadvantage score,” a well-used measure of SES: (1) percent living below the poverty line, (2) percent of households that are headed by a female, (3) male unemployment rate, and (4) percent of families receiving public assistance.<sup>21</sup> The disadvantage score of the residential neighborhood (DSR) was categorized into percent quartiles based on its distribution and referred to as very-low- (the most disadvantaged), low-, high-, and very-high-SES areas. Lower scores refer to higher-SES areas.

**Operationalizing distance between residence and grocery store location.** Because direct information measuring grocery store characteristics did not exist, a proxy measure for grocery store quality was created. Using the same process described for residential neighborhoods, a disadvantage score was created for the census tract where the respondents indicated that they shopped for groceries (DSG). The difference in the continuous disadvantage scores between the residential and grocery store neighborhood was calculated ( $DSG - DSR$ ). “ $DSG - DSR$ ” indicates whether the individual shopped in an area more or less advantaged to his/her residential area, where higher scores represent shopping in a more disadvantaged neighborhood compared to the individual's area of residence.

The  $DSG - DSR$  for each person was then averaged for each census tract indicating the average  $DSG - DSR$  of individuals residing in that census tract when grocery shopping.

Using the same process to operationalize exposure to grocery stores, the difference in the continuous disadvantage scores was calculated between the residential neighborhood and other sites of respondent's daily activities. These included sites of worship, work, entertainment, and medical visits.

Exact locations of the individual's residence and grocery store were unknown. The only known information was that regarding the census tracts where the residence and grocery store were located. Distances between the residence and grocery store were estimated to be from the centroid of the residential census tract to the centroid of the grocery store census tract. Centroid is defined as the geographic center of the census tract.

The centroid-to-centroid distances were categorized into four roughly equivalent-sized groups. The distance categories were those individuals who stayed within their census tract to

**Table 1.** Selected characteristics of respondents: L.A.FANS, 2000-2001

		Those who shop in same census tract as residence (n=468)	Those who shop in neighboring census tracts (n=889)	Those who shop beyond neighboring census tracts (n=787)	Total sample (N=2144)
Family income (\$)	Mean	37,789	51,837	59,857	51,714
Age	Mean	39.8	39	39.7	>39.5
% married		45	50	52	50
% own car		70	77	79	76.2
% female		54	56	59	56.7
% employed		65	70	67	67.8
% college		13.5	20	22.5	19.6
					<b>N</b>
<b>Race/ethnicity (%)</b>					<b>(% total sample)</b>
Latino		23	42	34	1184 (55.2)
African American		15	40	45	185 (8.6)
White		23	39	38	549 (25.6)
Asian		13	51	36	145 (6.8)
Other		23	34	43	77 (3.6)
Residential area					
<b>SES (%)</b>					
Very low		21	40	39	804 (37.5)
Low		23	41	36	658 (30.7)
High		34	29	37	339 (15.8)
Very high		10	59	31	343 (16)

L.A.FANS, Los Angeles Family and Neighborhood Study; SES, socioeconomic status.

shop for their own groceries (21.8%), those who traveled 0.01 to 1.0 mile (29.7%), those who traveled between 1.01 and 1.75 miles (23.34%), and those who traveled 1.76 miles or more (25%). Distance was analyzed as a categorical variable; those who traveled 0 miles (within their residential census tract) for their groceries were used as the reference category.

**Sociodemographic controls.** Models were controlled for (1) gender (female=1), (2) age (logged), (3) education (college educated=1; less than college educated=0), (4) race/ethnicity (Latino, black, Asian, others, or white [Asian, others, and missing were combined with whites as the reference group because of small numbers]), (5) employment (employed=1; all other=0), (6) marital status (married=1; all other=0), and (7) income (logged). Age and income were logged because their distribution was skewed.

## Statistical Analyses

Multilevel linear regression models using SAS PROC MIXED, version 8.2 (SAS Institute Inc., Cary NC, 1999–2001),<sup>22</sup> were used in 2005 to estimate simultaneously the direction of association between BMI and the individual sociodemographic variables, distances between location of residence and grocery stores, and aggregate residential neighborhood demographics.

## Results

### Descriptive Statistics

The 2144 L.A.FANS respondents were predominantly young (mean age 39.5) and Latino (55.2%), as shown in the last column of Table 1. Thirty-eight percent of

the adult sample resided in the lowest-SES neighborhoods; more than 68% of the total sample lived in the two lowest-SES neighborhood quartiles.

Only 13% of Asians and 15% of blacks shop within their own neighborhoods for their groceries, and proportionally, more blacks (45%) travel farther than any other race for their groceries, consistent with previous work showing that fewer supermarkets were located in areas where blacks live.<sup>12,13</sup>

Individual-level demographic characteristics were associated with variability in BMI. For a 5'5" individual, 1 BMI unit is equivalent to approximately 6 lb, such that 0.762 BMI units=4.7 lb; 1.5 BMI units=9 lb; and 2.4 BMI units=14.5 lb. Model A of Table 2 shows that owning a car was associated with an additional 0.762 BMI units, Latino ethnicity with an additional 1.5 BMI unit, and black race/ethnicity with an additional 2.4 BMI units. Log age was also associated with higher BMI. College education was associated with lower BMI. Family income, being married, and being female were not associated with BMI. Holding all other factors constant, Table 3 illustrates the association of car ownership, college education, race/ethnicity, and weight in an average 5'5", 40-year-old, single, employed male who lives in a very-high-SES area.

### Multilevel Linear Regression Models

When area effects of residential SES were placed in the model (Table 2, Model B), there was a gradient effect;

**Table 2.** Mean tract SES difference between residential and grocery store neighborhoods and distance traveled to grocery store predicts body mass index

	Total sample (N=2144)			
	Model A	Model B	Model C	Model D
Residential SES: very low		1.51***	2.11****	2.28****
Residential SES: low		1.17**	1.50***	1.64****
Residential SES: high		0.89*	1.05*	1.18**
Residential SES: very high			Reference category	
Disadvantage score difference (DSG-DSR) <sup>a</sup>			0.23**	0.24**
<b>Distance between residence and grocery store</b>				
≥1.76 miles				0.78*
1.01–1.75 miles				0.10
0.01–1.0 miles				0.22
0 <sup>b</sup> miles			Reference category	
Own car	0.76**	0.90***	0.91***	0.87**
College educated	–1.32****	–1.05***	–1.09***	–1.13****
African American	2.40****	2.03****	1.97****	1.90****
Latino	1.50****	1.12****	1.06****	1.06****
Married	0.27	0.36	0.38	0.34
Employed	0.46	0.52*	0.52*	0.54*
Log age centered	1.73****	1.65****	1.65****	1.66****
Log income centered	0.03	0.00	0.00	0.00
Female	–0.33	–0.31	–0.32	–0.34
Intercept	24.96	23.88	23.65	23.29
AIC	12,921	12,914	12,910	12,908.6
U <sub>oj</sub> ( <i>p</i> values)	0.1746 (0.1666)	0.1761 (0.1431)	0.1228 (0.206)	0.089 (0.27)
R <sub>ij</sub>	23.82	23.69	23.66	23.3

<sup>a</sup>Disadvantage score difference between grocery store neighborhood and residential neighborhood. (Negative score: grocery store is located in a higher SES area compared to residential area. Positive score: grocery store is located in a lower SES area compared to residential area.)

<sup>b</sup>0 miles implies that grocery store census tract is located in same area as residential census tract.

\**p*≤0.05;

\*\**p*≤0.01;

\*\*\**p*≤0.001;

\*\*\*\**p*≤0.0001 (all bolded).

AIC, Akaike's information criterion; DSG, disadvantage score for grocery store tract; DSR, disadvantage score for residential tract; SES, socioeconomic status.

living in a very-low-SES area was associated with a 1.51-unit increase in BMI (9.2 lb in a 5'5" individual), whereas living in a lower-middle-SES area was associated with a 1.17-unit increase in BMI (7 lb in the same individual) compared to living in the very-high-SES quartile. Even living in an upper-middle-SES area compared to the highest-SES quartile was associated with a 0.893 BMI-unit increase (5.4 lb for a 5'5" individual).

Independent of individual-level factors and residential-level SES, individual exposure to grocery store neighborhoods with greater disadvantage relative to the individual's residential neighborhood increased

BMI (data not shown). This implies that the BMI of an individual is a function of this individual's choice of grocery store.

Then the question was raised whether individual BMI might vary among census tracts depending on where the average individual in that census tract shopped. Grocery-store neighborhood scores across individuals within a census tract were averaged, and this aggregate mean grocery-store neighborhood score was used as a predictor at the neighborhood level. This method showed that if the average individual shopped in an area of lower SES compared to the residential tract, any

**Table 3.** Factors associated with weight (lb) in average 40-year-old, 5'5", single, employed male who lives in very-high-SES residential area

Car owner	College graduate	Race/ethnicity		
		White	African American	Latino
Yes (+4.7)	Yes (–7.9)	139.4	154.4	148.8
	No	147.3	162.3	156.7
No	Yes (–7.9)	135.1	149.7	144.1
	No	143.0	157.6	152.0

SES, socioeconomic status.

**Table 4.** Mean difference between residential area SES and grocery store SES

	Residential SES area (n=468) (DSR)	Those who shop in neighboring census tracts (n=889)	Those who shop beyond neighboring census tracts (n=787)	All shoppers (N=2144)	N=2144 (% total sample)	
Mean difference (SD) between residential area SES and grocery store area SES <sup>a</sup>	Very disadvantaged	4.67 (1.87)	-1.40 (1.64)	-1.48 (1.37)	-1.41 (1.43)	804 (37.5)
	Disadvantaged	0.5 (0.66)	-0.34 (1.44)	-0.48 (1.64)	-0.34 (1.38)	658 (30.7)
	Advantaged	-1.66 (0.58)	-0.30 (0.53)	0.78 (0.77)	0.40 (0.69)	339 (15.8)
	Very advantaged	-3.47 (0.19)	1.17 (1.16)	1.34 (1.20)	1.11 (1.18)	343 (16)

<sup>a</sup>Positive scores imply that grocery stores lie in SES areas more disadvantaged than residential area. Negative scores imply that grocery stores lie in SES areas more advantaged than residential areas.

DSR, disadvantage score for residential tract; SD, standard deviation; SES, socioeconomic status.

single individual's BMI from that census tract was higher (Table 2, Model C). The model to predict individual BMI using aggregate mean grocery-store neighborhood score improved the fit better than the model using information regarding the grocery store location frequented by the individual.

Table 4 shows that in a low-SES area, the average person shops at grocery stores located in areas with a neighborhood indicator score better than the neighborhood where they reside. (A negative score indicates that the grocery store census tract is located in a higher-SES area than the residential neighborhood census tract.) Because a one-unit SES difference between residential and grocery store neighborhoods changes BMI by 0.229 units, the BMI of a resident from a low-SES area can range 1.5 BMI units (9.2 lb for a 5'5" individual) over a range of two standard deviations (SD) of grocery store SES; in other words, if the average resident from a low-SES area shops in an area with a neighborhood indicator score of -3.98 (-2 SDs from the mean), a 5'5" individual will weigh 9.2 lb less than if he or she lived in a low-SES area where the average resident shops in an area with a neighborhood indicator of 2.74 (+2 SDs from the mean).

Although the association was not as strong, when the model included those respondents who were missing grocery store locations, aggregate grocery store neighborhood indicators continued to remain an independent predictor of BMI and, similarly, increased the association between residential neighborhood disadvantage and BMI, just as it did in models where respondents were excluded who were missing grocery store locations.

In addition to the independent effect of grocery store location on weight, an increase in the association between residential neighborhood SES and BMI was seen. When grocery store neighborhood indicators were not included, individuals who lived in very-low-SES

areas were 1.51 BMI units (9.1 lb for a 5'5" individual) higher than individuals who lived in very-high-SES areas (Table 2, Model B). When models included grocery store neighborhood disadvantage indicators, the association between BMI and very-low-residential SES became stronger, increasing 39% (or an additional 3.54 lb) (Table 2, Model C). The magnitude of increase was seen at all residential SES levels, but was greater in magnitude in the lower-SES areas.

Independent of individual-level factors and residential-level SES, individual exposure to neighborhoods of worship, medical care, entertainment, and work was not associated with BMI (data not shown).

### Distance to Grocery Store Locations

When distance between the centroids of the individual's residential neighborhood and the grocery store that the individual frequented was included in the model (Table 2, Model D), distance  $\geq 1.76$  miles was an independent predictor for a BMI increase of approximately 0.775 units (4.6 lb for a 140-lb, 5'5" person). Distance  $< 1.76$  miles was not an independent predictor of BMI. As in Model C, Model D shows an increase in the association between aggregate residential neighborhood indicators and BMI when the models were adjusted for distance traveled.

### Interactions

Interaction effects between residential SES areas and aggregate differences in SES between residence and grocery store locations show that BMI is significantly higher when individuals in lower-SES areas lived in census tracts where the average individual was exposed to relatively lower-SES areas when shopping for groceries compared to individuals who lived in the highest-SES areas. There is no interaction between distance and residential SES.

## Discussion

Body mass index increased when individuals shopped for groceries in more-disadvantaged neighborhoods but was not influenced by the location of worship, medical care, entertainment, or work. This suggests a unique relationship between the neighborhood SES of the grocery store and BMI, supporting the notion that the neighborhood SES of grocery stores most likely is a proxy measure for a quality about grocery stores that influences BMI through diet. The fact that locations of worship, work, medical visits, and entertainment do not predict BMI suggests that these influences do not participate in the causal pathway; alternatively, census tract SES may not represent the factors at sites of worship, work, medical visits, and entertainment that may have an impact on BMI.

Interestingly, the better predictor of BMI was not the individual's specific choice of grocery store but the location of where the average resident shopped (although both measures were statistically significant). This suggests a group-level influence that might be related to pressures to conform to local norms. The behavior of the average within the census tracts, by frequenting grocery stores of a certain quality, may directly influence the purchasing-related behaviors of other individuals frequenting very different kinds of grocery stores, or indirectly influence their energy balance behaviors through other means, such as in food preparation, frequency of eating out, and exercise. "The population can be viewed as a network of interconnected actors . . . influencing (one another) . . . directly and indirectly . . . [and] behaving as a collective [unit]."<sup>23</sup>

On the other hand, it could be purely the influence of SES, the association between BMI and grocery stores being a simple coincidence of residents shopping at the nearest or most convenient grocery store. However, the only plausible mechanisms through which SES could be causally related to BMI must be through diet or energy expenditure, or through a direct effect on metabolism through what has become known as allostatic load.<sup>24,25</sup>

The correlation between average disadvantage score of census tracts adjacent to residential tracts and DSG was higher than 0.7 (data not shown), and using average disadvantage score of census tracts adjacent to residential tracts, instead of DSG, produced very similar results (data not shown). This suggests that surrounding neighborhoods influence BMI; this association does not shed any light on the mechanism through which it operates, but a mechanism of how area SES might influence BMI is provided here.

When controlling for grocery-store census tract SES, the association between residential census tract SES and BMI becomes stronger. In the same study, exposure to other environments appears to explain the variability of effect that the residence tract has on the

health of individuals who live there.<sup>19</sup> Likewise in this study, the association between residential neighborhoods and BMI increases in magnitude when a third variable, grocery store SES, is included in the models. When a confounding or mediating effect is removed statistically and increases the magnitude of association between the independent and dependent variable, the change indicates the existence of suppression.<sup>26</sup> In the same study, exposure to other environments negatively confounded and suppressed the association between health and residential neighborhoods;<sup>19</sup> in the present study, exposure to grocery stores is most likely in the causal pathway, thereby mediating (through diet) and suppressing the association between residential neighborhoods and BMI. Teasing out factors that make individuals and communities more or less susceptible to environmental influences clarifies the true effect of the environment. Previous studies lacking information regarding the location of grocery stores that people frequent may account for the weak results between residential neighborhoods and BMI.<sup>3-6,18</sup>

What explains the association of residential environments on BMI after accounting for the location of grocery stores? Most low-income households (90%) purchase food from supermarkets,<sup>27</sup> which are associated with better-quality foods,<sup>28</sup> but because many low-income people report making large food purchases once per month (45% getting rides with friends or relatives or walking<sup>27</sup>), there may be greater reliance on neighborhood convenience stores to supplement perishable food items. Neighborhood convenience store quality appears to vary by area SES,<sup>10</sup> and the quality and availability of these perishables may affect BMI. Because food stamp recipients and the elderly cite that proximity and cost prevented them from shopping at supermarkets,<sup>27</sup> neighborhoods with a greater population of poor and elderly may be more greatly affected by these smaller neighborhood grocery stores. In addition, because area SES measures are associated with the density of fast-food outlets<sup>29</sup> and the quality of restaurant foods,<sup>30</sup> and because 32% of total calories ingested by Americans are acquired from foods prepared and eaten outside the home,<sup>31</sup> neighborhood differences in BMI may be a result of neighborhood variance in the availability of other foods besides those found in grocery stores. Neighborhood differences in BMI also may be a result of neighborhood differences in what people purchase regardless of grocery store quality and energy expenditure, that is, physical activity.

Finally, longer distance traveled to the grocery store was associated with increased BMI. Although 75% of people shopped within a 1.75-mile centroid-to-centroid distance from their residential census tract, those who traveled 1.76 miles or more weighed almost 0.8 BMI unit (4.8 lb for a 5'5" person) more than those who travel 1.75 miles or less. Those who travel farther may purchase greater amounts of food in bulk, which has

been associated with increased weight.<sup>32</sup> This association persisted even after adjusting for car ownership, which can confound its association to BMI. Like other studies showing a positive association between BMI and car usage,<sup>33</sup> owning a car was associated with increased weight. Without taking into account distance and car ownership, the association between BMI and residential neighborhood SES is attenuated.

The proxy measure was a “relative” score and not the “absolute” measure of grocery store census tract disadvantage. Relative scores were used for a number of different reasons, both theoretical and practical. Practically, the effects of “absolute” measures of grocery stores were obscured because the SES of grocery stores and residential neighborhoods were highly correlated. When the SESs of grocery stores were categorized, there were few people who shopped in grocery stores located in areas greatly different in socioeconomic class from their residence resulting in small cells and power problems. “Relative” scores of grocery-store census tract SES eliminated the need to categorize the variable. Theoretically, shopping in a particular SES area may be an improvement or a step down depending on where one lives, and smaller relative differences may still have an impact.

### Limitations

Because data from the L.A.FANS first wave were used, the data are cross-sectional, and the data are yet unable to uncover the extent to which the effects of neighborhoods on BMI are causal. The problem of endogeneity cannot be resolved in the current data set. In this analysis, it is unknown whether it is the neighborhood that is associated with BMI or whether it is the choice of the individual to move to a particular area that is related to BMI that results in the neighborhood associations with BMI. The information was limited to the location of the primary grocery store frequented by the respondents. There was no information regarding food eaten outside the home, specific measures of grocery store quality, what was purchased or eaten, or individual physical activity patterns—all of which are better measures of individual energy balance compared to the proxy used.<sup>34,35</sup> A recent publication suggests that self-reported height and weight are often underestimated and vary significantly among different race/ethnic groups.<sup>36</sup> Under-estimation of self-reported height and weight would most likely under-estimate the associations found in this study, but variations among different race/ethnic groups would bias this study in directions unknown. The missing BMI and grocery store information (18% of total sample analyzed) could have biased the results, but because mean BMI of those missing grocery store information did not differ from the sample analyzed and because the mean difference in DSG – DSR of those missing BMI did not differ from

the sample analyzed, the likelihood of bias resulting from confounding is reduced.

### Conclusions

Combating the obesity epidemic requires an understanding of the mechanisms that produce it, both at the individual and neighborhood levels. Given an independent effect of grocery store location beyond the effect of neighborhood SES, and that the balance of diet and exercise is a critical mechanism by which BMI is determined, BMI may be the consequence of availability and access to affordable healthy food products that vary by geography. It is unclear whether this geographic variability affects all groups in the same way and whether responses are influenced by social characteristics. In order to change health, factors that affect dietary choice that are associated with area SES need to be identified and modified in order to contain the morbidity and mortality associated with obesity and its consequent conditions.

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