Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses

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Although the overall population in the United States has experienced a dramatic increase in obesity in the past 25 years, ethnic/racial minorities, and socioeconomically disadvantaged populations have a greater prevalence of obesity, as compared to white, and/or economically advantaged populations. Disparities in obesity are unlikely to be predominantly due to individual psychosocial or biological differences, and they may reflect differences in the built or social environment. The retail food environment is a critical aspect of the built environment that can contribute to observed disparities. This paper reviews the literature on retail food environments in the United States and proposes interrelated hypotheses that geographic, racial, ethnic, and socioeconomic disparities in obesity within the United States are the result of disparities in the retail food environment. The findings of this literature review suggest that poor-quality retail food environments in disadvantaged areas, in conjunction with limited individual economic resources, contribute to increased risk of obesity within racial and ethnic minorities and socioeconomically disadvantaged populations.

INTRODUCTION

Prevalence of overweight (BMI ≥25 kg/m^2) and obesity (BMI ≥30 kg/m^2) has increased dramatically in the United States in the past 25 years, with recent surveys reporting approximately 23% of adults categorized as obese.[1] Among children and adolescents, the prevalence of overweight has increased even more dramatically, having almost tripled since 1980.[2] While most international obesity rates are not as high as those reported in the United States, similar trends have been reported in other industrialized countries.[2,3]

Although overweight and obesity has increased across almost all racial, ethnic and socioeconomic levels, there are significant disparities within the overall US population, with higher BMIs associated with socioeconomic disadvantage and non-white race and ethnicity.[2,4–6] Employing multivariate regression techniques on reported height and weight data from the 2000 National Health Interview Study, Denney et al.[4] identified disparities in relative risks associated with overweight and obesity that persisted even after controlling for sex, age, marital status, region, family income, education, employment, smoking, biking/walking habits, and weekly vigorous activities. The relative risk ratios and 95% confidence intervals (95% CIs) for overweight among various racial/ethnic groups were as follows: 1.60 (95% CI, 1.44–1.76) for non-Hispanic blacks; 2.14 (95% CI, 1.32–3.47) for Native Americans; 0.5 (95% CI, 0.40–0.61) for Asian Americans; 1.21 (95% CI, 0.93–1.58) for Puerto Ricans; 1.54 (95% CI, 1.36–1.76) for Mexican Americans; and 1.57 (95% CI, 2.16–2.45) for Cuban Americans. It is important to note, however, that when stratified by sex, disparities by race and ethnicity are more consistently observed among women, as compared to men.[4,7–9] Disparities in obesity prevalence by race and ethnicity

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that persist even after controlling for socioeconomic position have been reported elsewhere.[5,6,10–12]

Low socioeconomic status (SES) has also been independently associated with increased risk for obesity in industrialized countries, particularly in women. In a recently published review of the literature on SES and obesity, McLaren[9] identified inverse associations between SES and obesity among women in 63% of cross-sectional studies conducted in industrialized countries. In contrast, the pattern of association between SES and obesity was less consistent among men in industrialized countries, with a general pattern of non-significance or curvilinearity with most socioeconomic indicators (income, material possessions, and occupation) and an inverse association with other socioeconomic indicators (education).

The central proximal causes for racial, ethnic, and socioeconomic disparities in the prevalence of obesity have traditionally been attributed to individual differences in health behaviors influencing calorie balance. Specifically, health behavior research in this area has found racial/ethnic, and socioeconomic differences in physical activity,[13] fresh fruit and vegetable consumption,[14] and dietary fat intake.[15] However, social ecological theory suggests that individual health decisions are determined by multiple levels of influence, including institutional, community, and broader physical, economic, and cultural environmental levels.[16] Recent attention to the contribution of built environments to obesity ("obesogenic environments") has led to the development of several frameworks for empirically describing retail food environments with respect to the availability, accessibility and pricing of foods associated with healthy eating behaviors.[17–21] These models identify environmental variables hypothesized to influence eating behaviors at the contextual level, a critical prerequisite for systematically examining nutrition environments using multilevel models that include information gathered at both the individual level and the environmental level.

The present report proposes three hypotheses that can serve as a framework for empirically testing the association between neighborhood retail food environments and obesity, and for examining the role environmental disparities may play in the prevalence of obesity among different racial/ethnic and socioeconomic groups within the United States. The proposed hypotheses to be tested include: 1) geographic differences in the access and availability of foods result in disparities in the retail food environment; 2) neighborhoods of low SES with high concentrations of racial/ethnic minorities have limited accessibility to and availability of healthy foods (poor-quality retail food environment), as compared to neighborhoods of relatively high SES and low concentrations of ethnic/racial minorities; and 3) individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density and to have higher rates of obesity, as compared to individuals exposed to high-quality food environments.

To provide preliminary evidence to test these hypotheses, a PubMed (National Library of Medicine, Bethesda, Maryland) search was conducted for the period 1992–2007 using the search terms "food environment", "nutrition environment", "food access", "food availability", and "obesity". Studies found through the electronic search were supplemented with others that were brought to our attention through the literature review. Abstracts of selected papers were screened and the study was included in the review if it was conducted in the United States and included a characterization of the retail food environment. Of the 13 studies included in the review, six employed an ecological research design, four used a cross-sectional approach, and three were multilevel studies. The studies are organized and discussed by hypothesis, and summarized in Tables 1–3.

HYPOTHESIS 1

Geographic differences in the access and availability of foods result in disparities in the retail food environment

The question of whether food environments differ geographically has been addressed by several investigations in a host of disciplines.[22–25] It is important to note, however, that differences in the retail food environment do not always represent disparities. Consistent with the definition of health disparities as outlined by Braveman,[26] disparities in the food environment refer to avoidable differences in the access and availability of healthful foods that systematically place socially disadvantaged groups at a further disadvantage for achieving healthy diets. Although it has been well documented that there are regional variations associated with food preference and price among ethnic groups and by region, disparities in retail food environments across neighborhoods are not well understood. However, observational measures of the quality of retail food environments, as characterized by availability, accessibility, and pricing, provide a useful method for comparing food environments between neighborhoods. A selective summary of recent research examining geographic differences in retail food environments using observational measures is presented in Table 1.

First introduced as a concept to examine disparities in food access and pricing in the United Kingdom, the term "food desert" has been used to describe areas with limited access to retail grocery stores.[27] Early research on food deserts was primarily concerned with exploring the

Table 1 **Summary of studies related to hypothesis 1 – geographic differences in the access and availability of foods result in disparities in the retail food environment.**

Reference	Location/setting	Food environment measure/method	Key findings
Morris et al. (1992)[72]	National (direct observation in rural areas)	Store type Market basket	a) Average food costs 20% higher in small/medium grocery stores as compared to supermarkets b) Fruit and vegetable availability limited in small/medium grocery stores c) 32% of residents in persistently poor rural counties redeemed food stamps at small/medium grocery stores as compared to 20% redemption rates in small/medium grocery stores
Chung et al. (1993)[44]	Minneapolis, MN (urban)	Store type Market basket	a) Chain stores prices significantly lower with greater variety of foods available as compared to convenience and small grocery stores b) Chain stores less prevalent in urban core areas c) Gap between urban core and suburban TFP basket significant and due primarily to presence of chain stores (chain stores $16 price reduction) with net impact of poverty to increase price of basket by approximately 3%
Horowitz et al. (2004)[49]	New York City – paired comparison: East Harlem (low SES, high ethnic minority pop.) and Upper East Side (high SES and low ethnic minority pop.)	Market basket	a) 18% of grocery stores in low SES neighborhoods stocked foods associated with recommended diet, as compared to 58% of grocery stores in high SES neighborhoods b) Only 9% of low SES bodegas carried recommended foods as compared to 48% of high SES bodegas
Block et al. (2006)[43]	Chicago – paired comparison 1. Austin (low SES, high ethnic minority pop.) 2. Oak Park (high SES and low ethnic minority pop.)	Market basket, including quality characteristics (participatory, direct observation)	a) Affluent neighborhoods had more chain grocery stores and supermarkets, while less affluent neighborhoods had more "low-cost" retail grocery chains b) Price differentials between neighborhoods not significant when controlling for store type c) Produce in Austin neighborhood rated as lower quality as compared to produce in Oak Park

impact of retail flight from the urban core, but it has since been extended to include rural areas that have experienced reductions in populations and concomitant reductions in the retail sector, including small-town supermarkets.[28–30] Research in this area examined the availability of supermarkets by store type (supermarket chain versus small grocer or convenience store) and pricing differentials among stores.[27,31] Of the four studies identified in this review (Table 1), there is relatively consistent evidence that the quality of the retail food environment (as measured by access and availability of healthy foods) varies geographically, and that low-quality food environments are associated with neighborhood deprivation. This contrasts with recently reported food-environment studies from the United Kingdom in which the association between the quality of the food environment and the sociodemographic structure of the neighborhood is mixed,[32] casting some doubt on the existence of "food deserts" within the United Kingdom.[30,33,34] While some of the variance associated with the relationship between retail food environment and neighborhood demographics in the United States and the United Kingdom can be linked with different patterns of residential segregation among countries, additional sources of variance may be associated with Modifiable Areal Unit Problems (MAUP) in which both scale and zoning influ-

Table 2 **Summary of studies related to hypothesis 2 – neighborhoods of low SES with high concentrations of racial/ethnic minorities have limited accessibility and availability of healthy foods (poor-quality retail food environment).**

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
Horowitz et al. (2004)[49]	New York City – East Harlem (low SES, high ethnic minority pop.) and Upper East Side (high SES and low ethnic minority pop.)	Ecological design, direct observation of food environment measures	Store type	Neighborhood-level variables: income, race/ethnicity	a) 18% of grocery stores in East Harlem stocked foods associated with recommended diet, as compared to 58% of grocery stores in the Upper East Side
			Price and availability of core foods needed for diabetic diet		b) Only 9% of East Harlem bodegas carried recommended foods as compared to 48% of Upper East Side bodegas
Zenk et al. (2005)[25] and Zenk et al. (2006)[52]	Detroit, MI	Cross-sectional design, chi-square and spatial regression, geographic information systems (GIS)	a) Store type	Individual-level variables: income, race/ethnicity	a) Quality of fresh produce lower in predominantly African American low SES (AA-low SES) communities as compared to racially heterogeneous middle-income communities (RH-mid SES), even after adjusting for store type
					b) 97% of AA-low SES live within 1 mile of > 8 liquor stores, as compared to 87.9% in RH-low SES, 59.3% AA-mid SES, and 0% RH-mid SES
			b) Distance to supermarket		c) Selection (#) and price of produce did not vary significantly by store type or neighborhood
				Neighborhood-level SES. Race- average income and racial composition	d) Within lowest SES group, African American neighborhoods have 2.7 fewer supermarkets within 3-mile radius as compared to white neighborhoods
			c) Price and availability of fruits and vegetables		e) Within lowest SES group, African Americans resided 1.1 miles further from supermarket as compared to white residents
					f) Interaction between race/ethnicity significant and inclusion of interaction term improved spatial regression model fit ($\chi^2 = 15.83$, $p < 0$)
Moore et al. (2006)[48]	North Carolina ($n = 75$ census tracts)	Cross-sectional design, Poisson regression, and multilevel analysis	Store type	Individual-level variables: income and race/ethnicity	a) Minority and racially mixed neighborhoods, after adjusting for population ratio, had more grocery stores and fewer supermarkets than white neighborhoods (African American tracts SR = 0.5; 95% CI 0.3–0.7; mixed tracts SR = 0.7, 95% CI 0.5–0.9)
	Maryland ($n = 276$ census tracts) New York ($n = 334$ census tracts)			Neighborhood variables: average income and racial composition Model adjusted for confounders, including population density	b) Lower income neighborhoods had half as many supermarkets as compared to affluent neighborhoods (SR = 0.5; 95% CI 0.3–0.8)

Table 2 **Continued**

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
Baker et al. (2006)[47]	St. Louis, MO ($n = 220$ census tracts)	Ecological design, direct observation of food environments, spatial clustering statistics	a) Supermarket audit tool and creation of z score	a) Neighborhood variables: % below poverty level and race/ethnicity at census tract	a) Spatial clustering of supermarkets (unadjusted and without including quality ranking) was not significant ($p < 0.50$); however, clustering by race/ethnicity was observed
					b) Spatial clustering of supermarkets using quality scores (z score from audit) was significant ($p < 0.01$; $p < 0.03$) with supermarkets in highest two quality tertiles clustered in census tracts with >75% white and <10% below poverty
Powell et al. (2006)[40]	National	Ecological design, multivariate analysis	a) Store type	a) Neighborhood variables: income, race/ethnicity	a) Low-income neighborhoods had 25% fewer supermarkets as compared to middle-income neighborhoods ($p < 0.01$)
				b) Regional/other confounders: population density, region, degree of urbanization	b) After controlling for income and other covariates, the availability of supermarkets in African-American neighborhoods was only 48% of white neighborhoods ($p < 0.01$).
					c) Hispanic neighborhoods have 32% as many supermarkets as compared to non-Hispanic neighborhoods ($p < 0.01$)
Morland et al. (2007)[53]	Brooklyn, NY	Cross-sectional design, direct observation, Poisson regression	a) Store type	a) Neighborhood racial segregation	a) Prevalence of supermarket varied by neighborhood composition, with white, racially mixed, and black areas having 0.33, 0.27, and 0.0 supermarkets per census tract, respectively
			b) Availability of fresh, canned, frozen and prepared produce	b) Neighborhood confounders: population density and neighborhood wealth (median house value)	b) 64% of fresh produce surveyed had a higher presence in predominantly white areas, as compared to 31% in racially mixed and 5% in predominantly black areas

Table 3 **Summary of studies related to hypothesis 3 – individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density, and higher rates of obesity, as compared to individuals exposed to high-quality food environments.**

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
Morland et al. (2002)[58]	North Carolina, Maryland, New York ($n = 10,623$)	Cross-sectional design, multilevel analysis, geographic information systems	Fruit and vegetable intake	a) Individual-level variables: income, educational attainment, region, race/ethnicity	a) After adjusting for income and education, five times as many supermarkets were available in neighborhoods with >75% white population; only 8% of African Americans lived in census tract with supermarket ($p < 0.01$) b) African Americans living in the same census tract as a supermarket were more likely to meet the dietary guidelines for fruit and vegetable consumption (RR = 1.32; 95% CI 1.40–1.80). This effect did not extend to whites (RR = 1.11; 95% CI 0.93–1.32)
				b) Neighborhood variables: store type, SES, race/ethnicity	c) Relationship between residence in same tract as supermarket exhibited dose-response effect, with a 32% increase in fruit and vegetable consumption among African Americans corresponding for each additional supermarket (RR = 1.32; 95% CI = 1.08–1.60)
Morland et al. (2006)[42]	North Carolina, Maryland, New York ($n = 10,623$)	Cross-sectional design, multilevel analysis, geographic information systems	a) Body mass index	a) Individual-level variables: income, race/ethnicity	a) Presence of a supermarket within a census tract was associated with a 9% lower prevalence rate of overweight (PR = 0.91; 95% CI 0.87–0.95) and a 22% lower prevalence rate of obesity (PR = 78; 95% CI 0.67–0.85) and a 12% lower prevalence of hypertension (PR = 88%; 95% CI 0.79–0.97)
			b) Hypertension	b) Neighborhood-level variables: store type, race/ethnicity, income	b) Adjustment for socioeconomic and physical activity behaviors resulted in an attenuation of effect for overweight (PR = 0.94; 95% CI 0.90–0.98), and obesity (PR = 0.88; 95% CI 0.75–0.95)
			c) Other CVD risk factors		c) Presence of convenience store within a census tract was associated with increased prevalence of overweight (PR = 1.07; 95% CI 1.02–1.12); obesity (PR = 1.19; 95% CI 1.05–1.25), and hypertension (PR = 1.12; 95% CI = 1.01–1.25) d) Greatest prevalence of overweight and obesity found in communities with combination of no supermarkets and one or more grocery stores and/or convenience stores

Table 3 **Continued**

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
Inagami et al. (2006)[61]	Los Angeles, CA ($n = 2620$)	Cross-sectional design, multilevel analysis	a) Body mass index	a) Individual-level variables: distance to shops, shop disadvantage score, car ownership, shopping patterns (within/outside of census district). Controlled for gender, age, education, race/ethnicity, employment, marital status, income	a) 13% of African Americans and 15% of Asians shop within their own census tract, as compared to 23% of whites b) Owning a car associated with additional 0.762 BMI units; Latino ethnicity associated with additional 1.5 BMI units; and African American ethnicity associated with 2.4 BI units ($p < 0.01$) c) College education associated with 1.32 reduction in BMI ($p < 0.01$) d) Family income, marital status and gender not associated with differences in BMI
				b) Neighborhood variables: neighborhood-level disadvantage (% < poverty + % female households + male unemployment + % public assistance)	e) Gradient effect associated with living in a very low SES area with 1.51 unit increase in BMI, as compared to a 1.17 unit increase in BMI for lower-middle SES, and 0.893 unit BMI increase for highest SES f) When model includes grocery store disadvantage, living in very-low-SES neighborhood results in 2.11 unit increase in BMI ($p < 0.0001$) g) Shopping distance ≥1.76 miles independently associated with 0.775 unit increase in BMI ($p < 0.01$)

ence the relationships being tested.[32,34,35] Nevertheless, results pairing reduced access and higher prices have been noted by other researchers in the United Kingdom,[36–38] Canada,[39] and the United States.[40–44] Regardless of whether or not one adopts the "food desert" terminology, most research within the United States supports the hypothesis that there are disparities in the retail food environment that can be identified at the neighborhood level.[45]

HYPOTHESIS 2

Neighborhoods of low socioeconomic status with high concentrations of racial/ethnic minorities have limited accessibility and availability of healthy foods (poor-quality retail food environment)

The association between neighborhood racial, ethnic, and socioeconomic profile and food availability has been studied extensively within a variety of contexts and utilizing a number of different research techniques. A summary of recent research on the association between neighborhood-level characteristics and retail food environments is presented in Table 2.

Zenk et al.[46] used Geographic Information Systems (GIS) to examine the impact of racial and economic segregation on access to supermarkets in metropolitan Detroit, Michigan. They reported that socially disadvantaged neighborhoods comprised primarily of African Americans were, on average, 1.1 miles further from the nearest supermarket compared to predominantly white neighborhoods within the same socioeconomic classification. Baker et al.[47] also employed GIS to determine spatial distribution and clustering of supermarkets and fast-food outlets in St. Louis, Missouri. They found that mixed-race or white high-poverty areas were significantly less likely to have access to foods that enable adherence to a healthy diet, as compared to predominantly white, higher income areas. As in the Detroit study, residents in African American neighborhoods had significantly less access to supermarkets and other retail sources with "healthier" foods, regardless of income, as compared to predominantly white neighborhoods.

Similar results were reported by Moore and Diez Roux[48] in an investigation of the association of neighborhood characteristics with location and type of food stores in selected census tracks participating in the Multiethnic Study of Atherosclerosis. In their study, which included sites in North Carolina, Maryland, and New York, predominantly minority and low-income neighborhoods had significantly fewer supermarkets as compared to predominantly white and higher income communities, even after adjusting for different population densities across all sites. While there were significant differences in food environments (as measured by food store type) among the three sites studied, the finding that larger supermarkets were more prevalent in higher income and predominantly white areas has significant implications with respect to the availability of healthy foods, since supermarkets traditionally carry a larger array of food items.[21]

Although there is relatively strong evidence supporting the association of disparate retail food and nutrition environments among neighborhoods of differing SES and racial/ethnic profile in the United States, it is important to note that the methods employed in these studies influenced the strength of the relationship between neighborhood sociodemographics and food environments. Those studies that included direct observation of food environments using market-basket analysis[36,43,47,49] tended to show that the relationship between availability, pricing, and access to healthy foods was complex, and the association between neighborhood-level characteristics and food environment tended to be weaker, especially for pricing variables. Studies that utilized store type as a proxy for access to healthy foods[44,48] generally found a relatively strong association between neighborhood characteristics and food environment. There are clear tradeoffs when contrasting the two methods: the use of store type as an indicator of access and price associated with healthy foods allows larger and more diverse retail food environments to be studied feasibly; it is also supported by the strong associations found in the literature between store types, food availability, and food prices.[41,50–53] However, direct observation of food and nutrition environments (including market-basket analysis techniques) may allow for critical differences in quality to be noted, although variations in market-basket composition limit the ability to generalize results.

Despite these variations in research methods, there are consistent trends among results from studies conducted in the United States. Whether using objective approaches that measure the specific foods available or proxy measures looking solely at food-store type, there is an association in which socioeconomically disadvantaged neighborhoods with high proportions of racial and ethnic minorities have poorer quality retail food environments, as measured by access to and availability of healthy foods, compared to more affluent areas with comparatively small populations of ethnic and racial minorities.

It is imperative, however, to recognize the limitations of these studies with respect to understanding the causal linkage between food environments and obesity. Foremost, eating behaviors are influenced by a multitude of environmental factors operating at different levels of organization; these are mediated by psychosocial, demographic, and sociocultural factors that operate at the individual level. Although some research indicates that the availability of supermarkets (which stock a greater quan-

tity and variety of fruits and vegetables) is associated with greater adherence to recommended dietary practices at an individual level,[51,54–56] larger-scale and longitudinal studies using individual-level data, in conjunction with environmental data (beyond access and availability), are needed to further refine our understanding of the relationships among food access, availability, and obesity. As highlighted in hypothesis 3 of this paper, multilevel studies offer significant advantages for understanding the relationships among individual food behaviors, food access and availability, and obesity.

HYPOTHESIS 3

Individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density, and higher rates of obesity, as compared to individuals exposed to high-quality food environments

As highlighted in the studies reviewed above, a number of characteristics associated with the retail food environment (access, availability, and price) have been reported to differ significantly according to neighborhood socioeconomic and demographic characteristics. These differences parallel trends in which low SES and non-white race and ethnicity is associated with higher prevalence of obesity, particularly in women.[8,57] Although these studies suggest that the quality of retail food environments on a neighborhood level affect eating patterns at an individual level, their observational and cross-sectional design limit any causal inferences on the relationships among food environment, food choices, and obesity. Multilevel studies that permit the delineation of individual (compositional) from neighborhood (contextual) effects, hold promise for facilitating greater understanding of the role of retail food environments in promoting food choices associated with healthy eating patterns.

Morland et al.[42,58] utilized food-frequency data from individuals participating in the Atherosclerosis Risk in Communities (ARIC) study ($n = 10{,}623$) to estimate food intake at the individual level. This study found that the availability of supermarkets varied significantly by race, with five times more supermarkets located in census tracts in which whites dominated the population. More importantly for the purposes of exploring the impact of retail food availability on food intake, African Americans living in the same census tract with a supermarket were more likely to meet the dietary guidelines for fruit and vegetable consumption, a relationship that exhibited a dose-response effect with each additional supermarket located within their census tract. The resulting increase in fruit and vegetable consumption associated with availability corresponded with an average increase of 32% in fruit and vegetable consumption for each additional supermarket. While the inclusion of other food store types (grocery stores and restaurants) into the model had a slight effect on reported dietary intake, the effect was less clear and non-significant for fruit and vegetable intake. Interestingly, the significant protective effect of living within the same census tract as a supermarket did not extend to whites; in this population only a slight increase in meeting dietary fruit and vegetable requirements was associated with the presence of at least one supermarket. This finding suggests that social and cultural environmental factors, as well as the built environment, influence eating behaviors at the neighborhood level. The importance of social influences at the neighborhood level have been identified as critical when examining the increased risk associated with residence in a neighborhood with relatively high rates of obesity prevalence.[59]

In a companion study, Morland et al.[42] further analyzed the results of the ARIC study with respect to the association between retail food outlets (supermarkets, grocery stores, and convenience stores), obesity, and cardiovascular disease risk factors. In this study, they found the presence of one supermarket within an individual's census tract was associated with a 9% lower prevalence of overweight, 24% lower prevalence of obesity, and 12% lower prevalence of hypertension. Adjusting the model for socioeconomic and physical activity behaviors (leisure index, sports index, and work index) resulted in an attenuation of the influence of supermarkets on the prevalence of overweight, obesity, and hypertension. In contrast, residing in the same census tract as a convenience store was associated with an increased prevalence of overweight, obesity, and hypertension. The associations between overweight, obesity, hypertension, and the presence of convenience stores were slightly attenuated with the inclusion of sociodemographic and physical activity behavioral factors, but they remained significant after model adjustment. Of particular interest were the results obtained when looking at different combinations of access to supermarkets, grocery stores, and convenience stores and their associations with obesity. People living in areas with any combination of food stores, with the exception of only supermarkets and grocery stores, had a higher prevalence of overweight and obesity, as compared to those living in areas with only supermarkets. The greatest risk for an increase in obesity was associated with an absence of supermarkets in the census tract and the presence of one or more grocery and/or convenience stores. This finding is critical when juxtaposed against retail trends of supermarket consolidation and the location of supermarkets on the urban or suburban periphery.[60]

A recent study by Inagami[61] highlights the importance of examining not only localized neighborhood retail food environments, but also preferred grocery stores, when assessing the impact of retail food environment exposures. The study used individual-level data from the Los Angeles Family and Neighborhood Study survey that included self-reported weight and height measures (used to calculate BMI), as well as information about income, transportation (car ownership), and the location of the grocery store relied upon for grocery shopping.

Along with the expected findings that variability in BMI was associated with age, race/ethnicity, and education, multilevel analysis indicated a gradient between BMI and area-level SES measures that persisted among all neighborhoods, with a 1.51 unit increase in BMI between those residing in the lowest and highest SES neighborhoods. Car ownership was also independently associated with an increase in BMI of approximately 0.762 units. Choice of grocery store and distance to grocery stores were independent predictors of BMI, with shopping at grocery stores located within a higher SES area (along the SES gradient) associated with lower BMI and distances $\geq$1.76 miles predictive of a 0.775 unit increase in BMI. Significant interactions between residential SES and aggregate differences in SES between residence and grocery store location existed, with BMI significantly higher when individuals in lower SES areas lived in areas where the average individual frequented local (low SES) grocery stores, as compared to individuals who lived in and shopped in the highest SES areas.

The results highlighting the importance of shopping behavior offer important insight into the difficulties of utilizing local retail food environment as a single exposure variable. Instead, these results suggest that, at least within an urban context, the ability to shop in grocery stores in neighboring, more affluent neighborhoods potentially mitigates the impact of residing in a disadvantaged neighborhood.

As with other multilevel studies reviewed, the determination of causality is limited by the lack of temporal information, and reliance on food store type (while mediated by the integration of store location by area-level SES) as an indirect measure may have resulted in some misclassification of food environments. Lastly, as in all the studies reviewed here, life-course SES exposures (which would be assumed to be associated with life-course food and nutrition environment exposure), which have been suggested as a significant factor in the development of obesity, are not taken into consideration.[11,62,63]

CONCLUSION

Based on this review of the literature, we would like to suggest an omnibus hypothesis associated with the relationship between neighborhood retail food environments, SES and food choices associated with obesity. Specifically, as suggested by Figure 1, we hypothesize that while the quality of the retail food environment affects food choice and eating behaviors among both high and low SES populations, the economic (and perhaps social and cultural) resources available to those of higher SES have a protective effect on eating patterns. This effect is consistent with a cross-level confounding effect as described by Blakely and Woodward[64] in which an individual-level variable (SES) acts as a confounder on the ecological (food environment) variable. This hypothesis builds upon previous research suggesting that low SES and food pricing patterns discourage healthy eating on an individual level,[41,65,66] but it also incorporates critical neighborhood-level factors that contribute to unhealthy eating patterns and risk of obesity. Recognizing and measuring the multilevel influences of the retail food environment on eating behaviors (and risk of obesity) is a critical prerequisite for the development of multilevel interventions that address barriers and facilitators at both the individual and environmental level.

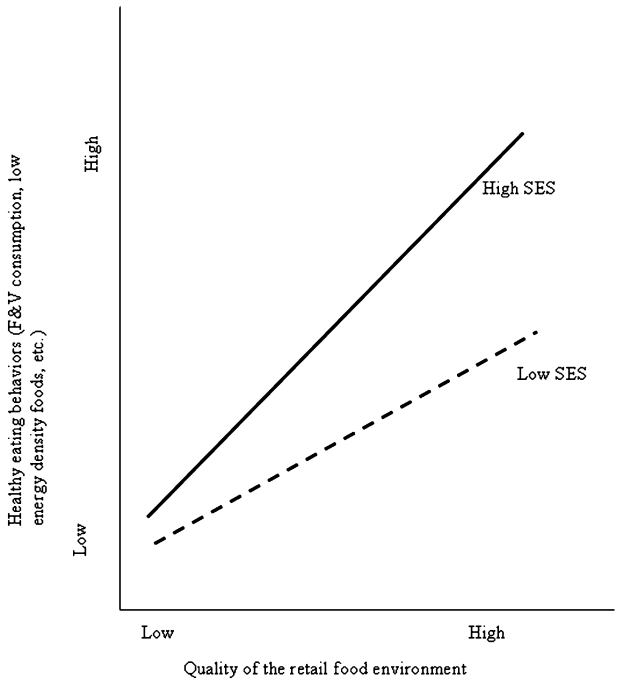

Figure 1 **Protective effect of socioeconomic status (SES) on moderating the impact of poor-quality food environment on eating behaviors linked to obesity.**

This hypothesis also explicitly acknowledges that while the presence of a high-quality food environment is a necessary condition for the adoption of healthy eating behaviors, it is not sufficient for ensuring healthy eating behaviors. One of the criticisms of much of the research on the relationship between food access and obesity is

that it assumes a relatively simplistic deprivation effect associated with poor-quality food environments.[34,67] The cross-level moderating effect proposed within this hypothesis recognizes that the health outcome of interest (healthy eating) is moderated by other environmental factors (such as transportation, social capital and culture) in addition to being mediated by individual-level characteristics, including food price.

The relationship between food environments and obesity is extremely complex, and it is unlikely that any single study will yield a complete and accurate picture of how changes in our local food environments have contributed to the obesity epidemic in the United States However, this review does highlight some critical gaps in our knowledge base that can potentially be addressed in future studies. One of the most critical research needs is for longitudinal studies that permit temporal associations to be determined between food and nutrition exposure and obesity. A recently released short paper highlights the potential for using reliable and valid historical data on grocery store location, and future studies should explore these data sources.[68] Longitudinal data associated with life-course exposure to food and nutrition environments would also be of great utility in understanding the cumulative effect of food environment exposures on eating behaviors and obesity.[63]

Another critical need is for studies that investigate food and nutrition environments in non-urban settings. Approximately 20% of Americans live in areas that can be classified as rural, and the prevalence of obesity is generally higher in rural as compared to urban areas.[24,69] Results from the Inagami[61] study showing driving distance as an independent predictor of BMI suggest that the significant distances rural residents drive to purchase foods may contribute to unhealthy eating patterns in these areas. Additionally, rural areas provide an opportunity to study the mechanisms underlying the relationship between food environments and eating patterns in the absence of significant socioeconomic and racial segregation in housing patterns.

Lastly, given the multiplicity of factors associated with weight gain at an individual level, studies are needed that involve direct observation of environmental correlates of physical activity, other health behaviors, and area-level socioeconomic correlates (particularly food insecurity).[8,70] Multilevel, mixed methods studies offer the potential to provide a more complete picture of the direct and perceived environmental influences on healthy behaviors.[71]

Understanding the role of food access and availability on food and nutrition environments, and ultimately on obesity, offers significant potential for the development of evidence-based interventions and policies to combat the growing epidemic of obesity in the United States and throughout the world. While a daunting task, a better understanding of these complex environmental interactions and impacts on obesity is a critical prerequisite for addressing the even more daunting health issues associated with obesity.

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