
Supermarkets, Other Food Stores, and Obesity

The Atherosclerosis Risk in Communities Study

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Background: Obesity is a leading public health concern, and although environmental factors have been hypothesized to play a role in the prevention of obesity, little empirical data exist to document their effects. The purpose of this study was to examine whether characteristics of the local food environment are associated with the prevalence of cardiovascular disease risk factors.

Methods: A cross-sectional study of men and women participating in the third visit (1993–1995) of the Atherosclerosis Risk in Communities (ARIC) Study was conducted in 2004. The analyses included 10,763 ARIC participants residing in one of the 207 eligible census tracts located in the four ARIC-defined geographic areas. Names and addresses of food stores located in Mississippi, North Carolina, Maryland, and Minnesota were obtained from departments of agriculture. Multilevel modeling was used to calculate prevalence ratios of the associations between the presence of specific types of food stores and cardiovascular disease risk factors.

Results: The presence of supermarkets was associated with a lower prevalence of obesity and overweight (obesity prevalence ratio [PR]=0.83, 95% confidence interval [CI]=0.75–0.92; overweight PR=0.94, 95% CI=0.90–0.98), and the presence of convenience stores was associated with a higher prevalence of obesity and overweight (obesity PR=1.16, 95% CI=1.05–1.27; overweight PR=1.06, 95% CI=1.02–1.10). Associations for diabetes, high serum cholesterol, and hypertension were not consistently observed.

Conclusions: Results from this study suggest that characteristics of local food environments may play a role in the prevention of overweight and obesity.
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Introduction

The U.S. Public Health Service has identified obesity as a leading health concern.¹ The prevalence of obesity has been increasing in the United States, and disparities in both conditions exist by gender, race/ethnicity, and socioeconomic status.^{2–3} For example, the prevalence of overweight and obesity is greater among nonwhite women compared to white, non-Hispanic women. In addition, a 50% higher prevalence of obesity has been reported in poor compared to nonpoor women.^{1,4}

The increasing rates of obesity have both health and economic consequences, because individuals who are obese are at greater risk of developing comorbidities.⁵ In particular, diabetes has been steadily increasing;

black Americans, Hispanic Americans, and those with lower education and income are more likely to develop the disease.^{6–8} The economic consequences of obesity has been estimated at 280,000 to 300,000 deaths per year,⁹ and the U.S. cost for treatment and lost wages is estimated to be over \$110 billion.¹⁰

The high prevalence of obesity results from the interaction of environmental, behavioral, and genetic factors. Although genetic factors are important for determining individual susceptibility to becoming overweight, broadly defined environmental factors such as changes in agriculture, food processing and marketing, transportation, physical demands of work, and the contextual effect of residential areas create the context for the population distribution of adiposity. These environmental factors affect obesity through their effects on physical activity and diet.

At the same time that the prevalence of overweight and obesity has been increasing in the United States, levels of physical activity have been decreasing, such that the Task Force on Community Preventive Services has made the recommendation for physical activity to combat these increasing rates.^{11,12} Environmental characteristics that have recently received attention as de-

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terminants of physical activity include aspects of urban sprawl,¹³ accessibility of recreational resources,^{14,15} and neighborhood safety.^{16,17}

Although the consumption of total fat and saturated fat has decreased over the past 30 years, the intake of calories and carbohydrates has increased.¹⁸ The consumption of specific food items such as soft drinks and sugars has also risen.^{19–23} These trends toward energy-dense diets are thought to be a result of a variety of factors including increasing portion sizes^{24–25} and changes in food production, marketing, and pricing.^{26–29} Energy-rich foods (i.e., sugars, breads, pastas) are less expensive, which may make these foods especially attractive to people with limited incomes. The increasing availability of pre-packaged foods has also been suggested as a factor contributing to the intake of energy-rich foods.^{30–31}

In addition, food availability at the neighborhood level has recently received attention as a possible environmental determinant of diet.^{32,33} Some investigators have documented disparities in the costs of foods^{34–36} among areas, while others have shown differences in the availability of certain types of food stores.^{34–41} Other researchers have focused on the types of foods available within food stores; for instance, Sallis et al.⁴² found that U.S. supermarkets offer a large variety of healthy foods. Other investigators support these findings in which associations between healthy diets and supermarket availability have been documented.^{43,44} More recent studies have begun to show an association between the availability of places to obtain foods and obesity.^{45,46} Little data exist on the contents of other types of food stores, such as convenience stores, that are assumed to carry a larger proportion of energy-dense foods. Since the food choices that people make are limited to what is available to them, and convenience is an important predictor for food habits,^{47,48} it is hypothesized that individuals living in areas with few food choices other than convenience stores may be more likely to adopt an energy-dense diet. Conversely, food environments offering a greater variety of healthy food options at affordable prices may lead to healthier food choices.

The objective of this study was to determine if there is an association between the availability of supermarkets, grocery stores, and convenience stores and cardiovascular disease (CVD) risk factors. Because of previous positive associations between diet and the availability of supermarkets,³⁴ we hypothesized that the presence of supermarkets would be associated with a lower prevalence of overweight and obesity among the Atherosclerosis Risk in Communities (ARIC) study participants. Because diet and obesity are also associated with other CVD outcomes, we further hypothesized that the presence of supermarkets would also be associated with a lower prevalence of diabetes, hypercholesterolemia, and hypertension.

Table 1. Description of participants, cardiovascular disease risk factors and local food environments: the Atherosclerosis Risk in Communities Study (*n*=10,763)

Characteristic	<i>n</i>	%
Black American	2496	23.2
Female	6014	55.9
Age (years)		
49–54	2316	21.5
55–59	2893	26.9
60–64	2665	24.8
65–69	2428	22.6
70–73	461	4.3
Income		
<\$5,000	407	3.8
\$5,000–\$7,999	393	3.7
\$8,000–\$11,999	609	5.7
\$12,000–\$15,999	738	6.9
\$16,000–\$24,999	1642	15.3
\$25,000–\$34,999	2027	18.8
\$35,000–\$39,999	2211	20.5
≥\$40,000	2736	25.4
Education		
Less than high school graduate	2248	20.9
High school graduate	3431	31.9
Some college	1122	10.4
Advanced degree	3962	36.8
Physical activity, mean (standard deviation)		
Leisure index	2.34	(0.57)
Sport index	2.50	(0.82)
Work index	1.85	(1.00)
Cardiovascular disease risk factors		
Overweight	7812	72.6
Obesity	3553	33.0
Diabetes	1680	15.6
High cholesterol	6461	60.0
Hypertension	4466	41.5
Food stores/service places		
Supermarket	2777	25.8
Grocery store	5324	49.5
Convenience store	8300	77.1
Full service restaurant	8570	79.6
Franchised fast food restaurant	6050	56.2
Limited service restaurant	4961	46.1

Methods

Study Sample

Individual-level data were obtained from the third visit (1993–1995) of the ARIC study. A population-based sample of residents was randomly sampled from Jackson City MS, Forsyth County NC, Washington County MD, and selected suburbs of Minneapolis MN.^{49,50} The retention rate for the end of the third visit was 82% overall, and better for white (85%) than black Americans (70%). Of 12,887 individuals, 91% of residential addresses were geocoded to 1990 U.S. census tracts. Participants were excluded if they moved out of the ARIC-defined area or had missing values for any covariate (*n* = 814). In addition, racial/ethnic groups other than black and white Americans were excluded due to the limited number of other racial/ethnic groups (*n* = 1310). Hence, the analysis conducted in 2004 included 10,763 individuals. The

University of North Carolina School of Public Health Institutional Review Board approved this study.

Measurement of the Local Food Environment

Census tracts, national geographic boundaries containing approximately 3000 to 4000 individuals, were used as proxies for neighborhoods. The ARIC participants were drawn from a total of 207 tracts distributed across the four sites. Business addresses of food stores and food service places were collected in 1999 from the local departments of environmental health and state departments of agriculture and were geocoded to census tracts. The 1997 North America Industry Classification System (NAICS) codes have been modified to define the types of food stores.⁵¹ Supermarkets were defined as large corporate owned "chain" food stores, distinguished grocery stores, or smaller non-corporate-owned food stores. Convenience stores included all food stores that carry a limited selection of foods, mostly snack foods, whether or not attached to a gas station. In addition to these food stores, other types of places where residents buy food were classified as full-service restaurants, franchised fast food, and limited-service restaurants. A more extensive description of this classification of food stores and food service places has been described previously.⁴¹ Types of places to obtain food, other than those mentioned above, were not included in these analyses because of their small proportion of annual sales of foods and beverages in the United States.⁵²

Definitions of Outcomes

Two categories of body weight (overweight and obesity), diabetes, hypertension, and hypercholesterolemia were used because of their importance as CVD risk factors and their relationship with diet. Overweight and obesity were defined based on BMI (weight in kilograms/height in meters squared), where individuals with a BMI of >25 to 30 were categorized as overweight and >30 as obese. Individuals were categorized as diabetic if they reported taking medications for diabetes, had glucose levels of ≥ 200 mg/dL, and/or 8-hour fasting glucose levels above 126 mg/dL. Individuals were considered hypertensive if they reported taking medication for high blood pressure within the last 2 weeks, or if the average of two successive blood pressure measurements resulted in a systolic measurement of ≥ 140 mmHg or a diastolic measurement of ≥ 90 mmHg. Respondents with serum total cholesterol levels of >200 mg/dL, or who reported taking cholesterol-lowering medications in the past 2 weeks, were classified as having high cholesterol.

Statistical Methods

Binomial regression was performed, using random effects generalized linear models with a random intercept for each census tract, to estimate prevalence ratios (PRs) of CVD risk factors associated with the presence of different types of food stores.⁵³ Each health outcome was modeled separately. Initial analyses were modeled with each type of food store and food service place fit using dichotomous variables representing any versus none of that type of facility within the census tract. Indicator variables were also constructed to represent the presence of specific combinations of types of food stores. Risk factor values for residents of census tracts that contained only

supermarkets were compared to levels of residents in areas with (1) supermarkets and grocery stores; (2) supermarkets and convenience stores; (3) supermarkets, grocery stores, and convenience stores; (4) grocery stores; (5) convenience stores; (6) grocery stores and convenience stores; and (7) no food stores. Models were adjusted for education, income, age, gender, race/ethnicity, and physical activity. Population density and smoking status did not change the effect estimate, and therefore were not included in the fully adjusted models.

Dichotomous variables were created for race/ethnicity and gender. Models were also adjusted for physical activity. Physical activity was assessed based on the Baecke questionnaire, and three indices were created based on weighted responses from questions about physical activity from (1) work, (2) leisure time, and (3) sports. These indices ranged from low (1) to high (5). A further description of how these indices were derived is reported elsewhere.⁵⁴ All analyses were conducted using SAS, version 8.2 (SAS Institute Inc., Cary NC, 2001).⁵⁵

Results

Most participants were white (77%) and reported household incomes of $\geq \$25,000$ (65%). Roughly half were aged ≥ 60 years (52%), female (56%), and educated beyond high school (47%). Nearly 75% were overweight, 33% were obese, and 16% had diabetes. Sixty percent of the participants had high cholesterol, and 42% had hypertension. In addition, most participants lived in areas with full-service restaurants (80%) and convenience stores (77%). Roughly half of the participants lived in areas with at least one grocery store (50%), franchised fast food restaurant (56%), or limited service restaurant (46%). However, only one quarter of the participants lived in areas with at least one supermarket (26%) (Table 1).

Table 2 describes the association between the presence of supermarkets, grocery stores, and convenience stores and CVD risk factors. The unadjusted associations are presented in Model 1. Model 2 includes adjustments for other types of food stores and food service places, whereas Model 3 also adjusts for individual-level risk factors.

The presence of supermarkets was associated with a lower prevalence of overweight, obesity, and hypertension. For instance, compared to people who lived in areas without any supermarkets, a 9% lower prevalence of overweight (PR=0.91, 95% confidence interval [CI]=0.87–0.95), a 24% lower prevalence of obesity (PR=0.76, 95% CI=0.67–0.85), and a 12% lower prevalence of hypertension (PR=0.88, 95% CI=0.79–0.97) was observed in areas with at least one supermarket. Adjustment for other food stores or food service places produced similar estimates (Model 2). Adjustment for sociodemographic characteristics and behaviors (Model 3) reduced associations between the presence of one or more neighborhood supermarkets and the prevalence of overweight (PR=0.94, 95% CI=0.90–

Table 2. Prevalence ratios of obesity, overweight, diabetes, high cholesterol, and hypertension associated with the presence of different types of food stores in census tract of residence

	Model 1 ^a		Model 2 ^b		Model 3 ^c	
	PR	95% CI	PR	95% CI	PR	95% CI
Supermarkets						
Overweight	0.91	(0.87–0.95)	0.91	(0.86–0.95)	0.94	(0.90–0.98)
Obesity	0.76	(0.67–0.85)	0.74	(0.66–0.84)	0.83	(0.75–0.92)
Diabetes	0.89	(0.75–1.05)	0.84	(0.71–1.00)	0.96	(0.84–1.10)
High cholesterol	0.99	(0.95–1.03)	0.99	(0.94–1.03)	0.98	(0.94–1.03)
Hypertension	0.88	(0.79–0.97)	0.84	(0.74–0.93)	0.92	(0.85–1.01)
Grocery stores						
Overweight	1.07	(1.03–1.12)	1.06	(1.02–1.10)	1.03	(1.00–1.07)
Obesity	1.24	(1.12–1.38)	1.21	(1.09–1.33)	1.07	(0.99–1.16)
Diabetes	1.34	(1.16–1.55)	1.33	(1.15–1.54)	1.11	(0.99–1.24)
High cholesterol	0.99	(0.96–1.03)	0.99	(0.95–1.03)	0.99	(0.95–1.03)
Hypertension	1.20	(1.09–1.31)	1.17	(1.06–1.28)	1.08	(1.00–1.17)
Convenience stores						
Overweight	1.07	(1.02–1.12)	1.06	(1.01–1.11)	1.06	(1.02–1.10)
Obesity	1.19	(1.05–1.34)	1.14	(1.02–1.29)	1.16	(1.05–1.27)
Diabetes	1.06	(0.90–1.25)	0.96	(0.81–1.14)	0.98	(0.86–1.12)
High cholesterol	0.99	(0.95–1.03)	0.99	(0.95–1.04)	1.00	(0.96–1.04)
Hypertension	1.12	(1.01–1.25)	1.07	(0.96–1.19)	1.08	(0.99–1.18)

^aModel 1 is unadjusted.

^bModel 2 includes all types of food stores and food service places: supermarkets, grocery stores, convenience stores, full service restaurants, franchised fast food, and other limited service restaurants.

^cModel 3 includes all types of food stores and service places, gender, race/ethnicity, age, income, education, and physical activity (leisure index, sports index, and work index).

CI, confidence interval; PR, prevalence ratio.

0.98), obesity (PR=0.83, 95% CI=0.75–0.92), hypertension (PR=0.92, 95% CI=0.85–1.01). In Model 3 the presence of supermarkets showed little association with the prevalence of diabetes or high cholesterol (Table 2).

The presence of grocery stores was positively associated with the prevalence of overweight, obesity, diabetes, and hypertension in unadjusted models. Compared to areas with no grocery stores, the prevalence of overweight individuals was 7% greater in areas with at least one grocery store (PR=1.07, 95% CI=1.03–1.12). Obesity was 24% more prevalent (PR=1.24, 95% CI=1.12–1.38), diabetes was 34% more prevalent (PR=1.34, 95% CI=1.16–1.55), and hypertension was 20% more prevalent (PR=1.20, 95% CI=1.09–1.31) in areas with grocery stores. However, these associations were attenuated in the fully adjusted models (Table 2).

The presence of convenience stores was also associated with an increased prevalence of overweight (PR=1.07, 95% CI=1.02–1.12), obesity (PR=1.19, 95% CI=1.05–1.34), and hypertension (PR=1.12, 95% CI=1.01–1.25). Estimates for overweight and obesity changed very little in the fully adjusted models. Other CVD risk factors were not strongly or consistently associated with the prevalence of convenience stores (Table 2).

Table 3 describes the associations between the prevalence of overweight and obesity and the presence of specific combinations of food stores. The ratios compare the prevalence of risk factors among people in

areas with different types of local food environments to the prevalence among people who live in areas that contain only supermarkets. The prevalence ratios in Table 3 are adjusted for other types of food stores, food service places, and for individual sociodemographic and behavioral factors. For example, people living in areas where supermarkets and convenience stores are the only types of food stores available have a 35% higher prevalence of obesity compared to people who live in areas where supermarkets are the only type of food store available (PR=1.35, 95% CI=1.05–1.73). In fact, with the exception of areas where only supermarkets and grocery stores are available, people living in areas with any combinations of food stores have a higher prevalence of both obesity and overweight, compared to people living in areas with supermarkets only. The greatest increase in obesity is observed in areas with grocery and/or convenience stores but no supermarkets.

Discussion and Conclusion

While the availability of supermarkets is associated with a decreased prevalence of obesity and overweight, the availability of grocery stores and convenience stores is associated with an increased prevalence of overweight and obesity among residents. Controlling for other types of food stores and food service places, including supermarkets, does not change the estimate, although estimates are attenuated after controlling for

Table 3. Adjusted prevalence ratios and 95% confidence intervals of associations between prevalence of obesity and overweight and eight different combinations of food stores available within neighborhoods

Description of all food stores available	n ^a	p ^b %	CT ^c	CT ^d %	Obese ^e %	PR	95% CI	Overweight ^f %	PR	95% CI
Supermarkets	432	4.0	10	4.9	20.8	1.00	Referent	62.3	1.00	Referent
Supermarkets and grocery stores	208	1.9	4	2.0	21.2	1.04	(0.71–1.53)	59.6	0.95	(0.81–1.12)
Supermarkets and convenience stores	1020	9.5	20	9.8	29.0	1.35	(1.05–1.73)	69.6	1.11	(1.00–1.23)
Supermarkets, grocery stores, and convenience stores	1117	10.4	24	11.8	27.1	1.28	(1.00–1.64)	67.4	1.09	(0.98–1.21)
Grocery stores	471	4.4	13	6.4	35.7	1.48	(1.12–1.94)	74.5	1.14	(1.01–1.27)
Convenience stores	2635	24.5	48	23.5	32.3	1.45	(1.16–1.82)	72.5	1.12	(1.02–1.23)
Grocery stores and convenience stores	3528	32.8	52	25.5	40.3	1.60	(1.28–2.00)	78.3	1.18	(1.08–1.30)
None	1352	12.6	36	17.6	28.1	1.28	(1.00–1.63)	68.9	1.08	(0.97–1.19)

Note: Adjusted for all types of food stores and service places, gender, race, age, income, education, and physical activity (leisure index, sports index, and work index).

^aNumber of participants.

^bProportion of all participants.

^cNumber of census tracts.

^dProportion of census tracts.

^eProportion obese.

^fProportion overweight.

CI, confidence interval; PR, prevalence ratio.

individual-level factors. Furthermore, analyses conducted to investigate the effects on specific types of restricted local food environments reveal that, after adjustment, the prevalence of obesity and overweight was lowest in areas that had only supermarkets and in areas that had a combination of supermarkets and grocery stores. Prevalence was highest in areas with grocery stores and convenience stores only.

Prevalence ratios for high cholesterol vary between 0.98 and 1.00 in all models for each type of food store, suggesting that this measure of serum lipids is not influenced by variations in local food environments in this sample. In contrast, PRs for diabetes and hypertension were in the same direction and, in some cases, larger in magnitude than those for overweight and obesity. However, confidence intervals for diabetes, in particular, were wider than intervals for the more prevalent risk factors. The relative ability to quantify the impact of the local food environments on risk factors is affected by the relative degree of measurement error in these endpoints as well as the sample size (e.g., overweight vs diabetes).

Although estimates of the impact of the local food environment on overweight and obesity are attenuated by adjustment for individual-level risk factors, these factors explain only a portion of the observed associations. The persistence of associations after adjustment for individual-level factors is compatible with a causal effect of the local food environment on diet and obesity. However, residual confounding by mismeasured individual-level variables (such as socioeconomic position or physical activity) or confounding by omitted variables (such as cultural preferences, shopping hab-

its, and individual biological determinants of energy balance) remains a possibility. However, the association of the local food environment with obesity is consistent with earlier work showing that it is associated with reported dietary intake; however, differences between racial/ethnic groups were not observed in these analyses. More importantly, cultural factors may not act as independent confounders, but may be influenced by the local food environment and associated marketing and advertising that differ between areas with supermarkets, grocery stores, and convenience stores.

Although these findings suggest that the local food environment deserves greater attention as a potentially important causal or contributing factor in the development of obesity, several important caveats are in order. First, the cross-sectional design of this study does not allow the establishment of a temporal relationship between the local food environment and obesity. Second, individuals were not asked where they shop for food, so misclassification may have occurred if the census tract does not represent the area relevant to the food shopping habits of a particular individual. For instance, reliance on the local environment for food may differ by other factors such as transportation use. This may be more of an issue for African Americans, as the proportion of households without a private vehicle in predominately black census tracts is 30% versus 7% in white neighborhoods. Third, we have assumed that the local food environment has remained stable between 1993 and 1999. Fourth, the possibility that obese individuals select neighborhoods with certain types of stores cannot be eliminated, nor can the possibility that market research locates supermarkets in areas where

individuals maintain a healthy body weight. Fifth, the local food environments that individuals have been exposed to over their life course may be a more relevant predictor of obesity levels in adulthood than the contemporaneously measured environment. Sixth, other neighborhood-level variables associated with the presence of different types of stores could also account for the findings. For example, neighborhoods with supermarkets may be safer and have more recreational resources. We attempted to account for neighborhood factors associated with physical activity by controlling for individual-level measures of physical activity, but other pathways linking neighborhoods to obesity could also play a role. Finally, the types of available food stores were used as crude estimates for availability and cost of healthy foods because there is some evidence that, at least in the U.S. context, supermarkets often offer a greater variety of healthy and affordable foods.^{42,56} However, a healthy food environment might be achieved in other ways such as multiple smaller healthy food stores, which could possibly create certain advantages such as increased walking (improving health outcomes through other mechanisms).

Ultimately, the public health significance of the local food environment on overweight and obesity is not a function of any independent effect of the environment on individuals; rather, it is a function of its causal role in facilitating or constraining individual choices and opportunities. Admittedly, investigating the effects of the local food environment on health is a complex task. Better approaches to the measurement of the food environment, as well as longitudinal and experimental studies will allow causal inferences to be drawn with confidence. Despite its limitations, however, and taken together with previous work, this study suggests that the local food environment may play an important role in the prevention of overweight and obesity.

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