Measuring the Local Food Environment and its Associations with Diet Quality

by

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Abstract

Using data from multiple economic sources and the Multi-Ethnic Study of Atherosclerosis, this series of studies examined associations of various features of the local food environment with sociodemographic characteristics of neighborhoods (study 1), agreement between alternative assessments of the food environment (study 2), and the relation between the food environment (characterized in several different but complementary ways) and the diet of residents (study 3). Results from study 1 indicate that in addition to fewer supermarkets in minority and poor areas there were also fewer fruit and vegetable markets, bakeries, specialty stores, and natural food stores. One of the major challenges in studying the effect of the environment on diet is the measurement of the local food environment. Most studies have used the presence of supermarkets as a proxy for the availability of healthy foods in neighborhoods, but the quality of supermarkets can vary substantially and other stores may also offer healthier options. Study 2 investigated the interrelation of two alternative ways of characterizing the local food environment. Measures of the availability of healthy foods in neighborhoods based on the survey responses of residents were found to be positively associated but not synonymous with GIS derived densities of supermarkets. Alternative ways of representing the environment may help to create more representative pictures of what resources are available. Empirical evidence relating the local food environment to diet quality is limited. Study 3 found that having better spatial access to supermarkets was associated with meeting dietary fat recommendations and following the types of diets associated with better health outcomes. Similarly when assessing the food environment using the survey responses of the participants and the aggregated responses of those who live in the same area, those living in the worst ranked areas were significantly less likely to follow a healthy diet. The local food environment varies across neighborhoods and may contribute to disparities and social inequalities in health. Research is needed to

evaluate additive and synergistic effects of individual-level and neighborhood-level interventions order to identify more effective approaches to stem the tide of obesity in the United States.

Chapter 1: Introduction

Factors related to access to healthy foods have received increasing attention due to the disproportionate amount of obesity among Americans and the severity of associated diseases (1-7) Although causal pathways have yet to be established, local food environments and residents' diets have been linked in observational studies (5;8-10) and in preliminary data from natural experiments(11).

Minorities and low income groups may be particularly disadvantaged with respect to access to healthy foods due to the differential spatial placement of food establishments outside of their communities and their subsequent dependence on food sources proximal to their homes which offer limited selections at higher prices (4;12-22). Consequently, the location of supermarkets and other food stores may adversely limit the ability of minorities and the poor to meet recommendations for a healthy diet and may contribute to health disparities in heart disease, obesity, and diabetes (23;24). For these reasons, establishing what specific features of the local food environment are related to resident's dietary behaviors may have important policy implications in terms of reducing health disparities.

The current literature on the impact of the local food environment on diet is limited in that analyses are based mainly on small geographic areas and incomplete characterizations of the food environment, usually restricted to the simple assessment of whether a supermarket is or is not present in the area. Smaller stores such as fruit and vegetable markets, specialty food stores, meat and fish markets, etc. within neighborhoods may have a compensatory effect by providing a plethora of nutritious options in the absence of supermarkets; however the relationships of these types of stores with diet quality have yet to be explored. Analyses are also based mainly on administrative areas which may not correspond to areas relevant to food purchasing behavior. GIS measures such as densities have not been used extensively to date and may more appropriately represent what resources are proximate to people's homes as opposed to the simple presence of absence of a supermarket in a census tract.

Rather than characterizing the local food environment by simply noting the presence of absence of stores, an alternative method is to rate the environment based on the survey responses of people who reside in these areas. Recent work has also highlighted the utility of measuring features of residential environments through the aggregation of survey responses using ecometric techniques (25;26). These approaches have not been used in work examining the local food environment. Using these techniques in measuring the local food environment may afford a more comprehensive assessment by offering insight into a different dimension of the food environment not captured in traditional methods (i.e. how individual rate the availability of healthy foods in their neighborhoods and how multiple people as a whole view their environment). Studies are needed to determine how residents' survey responses concerning the quality of their local food environment is associated with the types of stores available in areas and ultimately with diet quality.

With these factors in mind, using data from multiple sources and from the Multi-Ethnic Study of Atherosclerosis (MESA), the purpose of this project was to (1) examine associations of a more complete depiction of the local food environment with sociodemographic characteristics of neighborhoods, (2) investigate agreement between various ways of assessing the food environment, and (3) examine the relationship of the local food environment characterized in several different but complementary ways with diet quality.

1.1 Specific Aims and Hypotheses

Aim 1: Measuring the Local Food Environment Using Existing Data: Reliability, Stability, & Associations with Sociodemographic Characteristics

Published evidence on the local food environment typically center on the spatial availability of supermarkets, convenience stores, and small grocers in areas to the exclusion of other food establishments in neighborhoods. While it is documented that healthier options are offered by supermarkets (4;12-21) it may be possible that having a variety of other smaller stores in a neighborhood may provide a wide enough shopping base for residents to have access to healthier alternatives. Documenting a more complete depiction of the local food environment including what types of smaller stores may be available in neighborhoods is an important step in considering what types of environments may be supportive of a healthy diet.

It is also important to note that characterizations of the food environment may vary by different data sources and over time. Although both factors may significantly affect the validity and interpretation of study results regarding associations of the food environment and diet, neither the reliability of characterizations of the food environment over different data sources nor the stability of assessments over time have been investigated in the literature.

To address these gaps in the literature, this component of the project explored associations of a more complete enumeration of the food environment with sociodemographic characteristics of neighborhoods. In addition, we also assessed the agreement between measures of the local food environment derived from two independent data sources as well as the stability of the local food environment over a two year period. Specifically these relationships were examined in the following hypotheses.

Hypothesis 1a. High agreement was expected between characterizations of the local food environment derived from a commercial source of data and from a government economic census in assessments of the number food stores present in zip codes.

Hypothesis 1b. The local food environment assessed at the census tract level is expected to be relatively stable over the course of a two year period.

Hypothesis 1c. Various types of food stores (including food retailers other than supermarkets, grocers, and convenience stores) were expected to be differentially distributed across neighborhoods based on their racial and socioeconomic composition..

Aim 2: Survey vs. GIS Based Characterizations of the Local Food Environment

One of the major challenges in studying the effect of the local food environment on diet is measurement of the local food environment. Traditional locational measures may not accurately give information on the underlying measure of most interest and utility, what types of healthy foods are actually available to residents of areas. An alternative to using the presence or absence of stores in area is to characterize the environment using survey based assessments. Survey measures may tap into a different dimension of the food environment, i.e. what is actually available, than more traditional counts of stores in census tracts or GIS based measures. In the parallel body of work examining the availability of recreational resources with physical activity, results differ according to the measure used (27-29). No studies have investigated the relationship between survey based characterizations of the food environment and characterizations of the environment derived from locational GIS based measures. Documenting the interrelation between these types of measures of the environment is important for the interpretation of studies that use them. This component of the project addresses these issues specifically in three hypotheses.

Hypothesis 2a. GIS derived densities of supermarkets in the local area (defined as a 1 mile radius around the person's residence) were expected to be positively associated with the reported selection and quality of fruits and vegetables and selection of low fat products as indicated by survey responses.

Hypothesis 2b. The density of a diversity of smaller stores like fruit and vegetable markets, natural food stores, and specialty markets, in the absence of a supermarket were also expected to be positively associated with better reported availability of healthy foods as described above.

Hypothesis 2c. Associations of densities of supermarkets and smaller stores with self reported availability were not expected to be additive so that living in an area with both supermarkets and a diversity of smaller stores would not be more strongly associated with availability than living in an area with either of these features alone.

Aim 3: Associations of the Local Food Environment with Diet Quality: A Comparison of GIS and Survey Assessments

The current literature on the impact of the local food environment on diet is limited in that analyses are based mainly on administrative areas which may not correspond to areas relevant to food purchasing behavior. In addition, no studies to date have incorporated other types of measures of the quality of the local food environment including survey measures which may provide information on the foods actually available to residents of areas which is not captured by data on the location of food stores. However, characterizing the local food environment based solely on the perception of a study participant in whom diet is also assessed may be unreliable and could potentially result in spurious associations (sometimes referred to as same-source bias). Obtaining information on both the local food environment and dietary measures from the same source may not provide reliable estimates. Recent work has highlighted the utility of measuring features of residential environments through the aggregation of survey responses of multiple area residents using ecometric techniques (25;26). Using responses from those in the same neighborhoods who are not also being questioned about their diet may help to circumvent this bias by providing an independent source of information. These different approaches to characterizing the local food environment have not been contrasted in the literature and documenting their relationship may provide a more valid representation the food environment.

Furthermore all but one previous study measuring the impact of the local food environment on diet quality generally used reductionist approaches when assessing diet quality, i.e. measuring only individual components of a healthy diet like fruit and vegetable intake, which may not be sufficient to adequately represent an overall healthy diet. Because foods are not consumed in isolation and the potential for synergy between foods (30) measuring diet quality using empirically derived dietary patterns and a priori indices may provide additional useful insight into the relationship of the local food environment and dietary behaviors than reductionist approaches alone.

Consequently, this last component of the project examined associations of various dietary behaviors with three different methods of characterizing the local food environment in three hypotheses.

Hypothesis 3a. GIS derived densities of supermarkets in the local area (defined as a 1 mile radius around the person's residence) were expected to be positively associated with meeting dietary recommendations for fat and fruits and vegetable intake and having a healthy diet, defined by both an a priori index and an empirically derived dietary pattern.

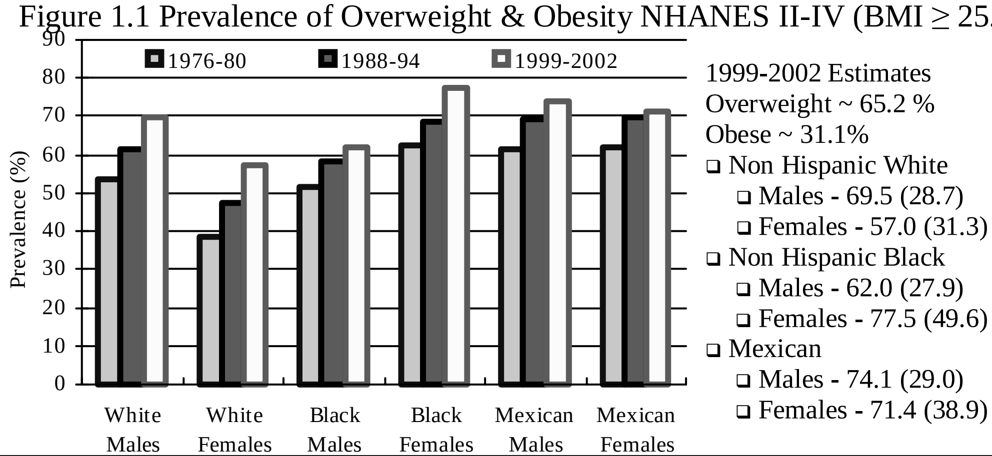
Hypothesis 3c. Survey based characterizations of the local food environment derived from survey responses to questions about the availability of healthy foods in neighborhoods were also expected to positively related to having a healthier diet and meeting dietary recommendations (as defined above).

Hypothesis 3d. Aggregate measures of the availability of healthy foods based on independent assessments of other residents in study participants' neighborhoods were also expected to be positively associated with healthier diets and meeting dietary recommendations in study (MESA) participants.

1.2 Background and Significance

With nearly two thirds of the US adult population either overweight or obese and classified as at risk of premature death by the National Institutes of Health (31), investigating the impact the local food environment may have on dietary choices is an important proposition because contextual interventions may be coupled with individual interventions to perhaps more effectively stem obesity in the United States. Over the past

Figure 1.1 Prevalence of Overweight & Obesity NHANES II-IV (BMI ≥ 25.0)



National Center for Health Statistics. Health, United States, 2004 with Chartbook on Trends in the Health of Americans. Hyattsville, Maryland: 2004.

three decades the prevalence of overweight and obesity have increased steadily for all gender and racial/ethnic groups as shown in figure 1 with blacks and Hispanics twice as likely to be overweight or obese as whites (31). Annually, 280,000-325,000 deaths have been estimated to be attributable to obesity among adults in the United States (32;33). This upward trend in obesity has been attributed mainly to sedentary lifestyles and high fat, energy dense diets although it has been difficult to parcel out which of the two is the primary culprit. Data from NHANES I-IV 1971-2000 indicates an increase in Americans average energy intake with decreases in total and saturated fat but increases in carbohydrates of approximately 168 kcal per day in men and 335 kcal per day in women (34). Consistent daily excess caloric intake of this magnitude alone may translate into an annual weight gain of about 18 and 35 lbs for men and women respectively. The other major contributor to obesity levels in the US is physical activity. Over time, physical activity has been conditioned out of daily lives in the forms of labor saving devices and advances in transportation and technology. Although comparable energy expenditure data over the same time period is not available as data on trends in caloric intake, it is apparent that Americans are engaging in more sedentary daily lifestyles with only 47.2% of Americans estimated as getting enough physical activity.

Although in its simplest form, overweight and obesity is caused by consuming more calories than expended, what Americans eat and how active they are is not only a matter of personal choice but is also affected by cultural, social, and environmental factors. Socioeconomic status, residential segregation, stigmatization, cultural ideal body size, food ideology, and individual metabolism all play significant roles in the prevalence of overweight and obesity (35-39). While numerous studies have been conducted on social, cultural, and psychological factors in the past decade in attempts to explain the higher prevalence of obesity with limited success (40), only recently has research turned to a more contextual explanation focusing on the role environmental determinants such as the proximity of fast food outlets and supermarkets may affect food choices (41). The individualization of risk, the practice of attributing risks to characteristics of individuals rather than to environmental or social influences affecting populations, has perpetuated the idea that risk is individually determined rather than socially determined, with lifestyle and behavior regarded as matters of free individual choice dissociated from the environment that shaped them (42). While it is unlikely in the case of obesity that the physical environment is the only culprit in the increasing rates of obesity and overweight in the population, it is improbable that health behaviors in any given population are immune from the surrounding environment. Increasingly, health outcomes like obesity and overweight are recognized not only as a result of individual behaviors such as eating and exercise habits, but also on the surrounding environment in which individuals live and work (43-49). In other words, individual lifestyle and behavioral choices are not only a function of personal choices, but also of cultural norms, economic circumstances, availability, and affordability. The limited literature that has focused on the relationship of obesity with environmental factors has indicated that these factors may play an important role in the ability of minorities and low socioeconomic populations to meet recommendations for a healthy diet.

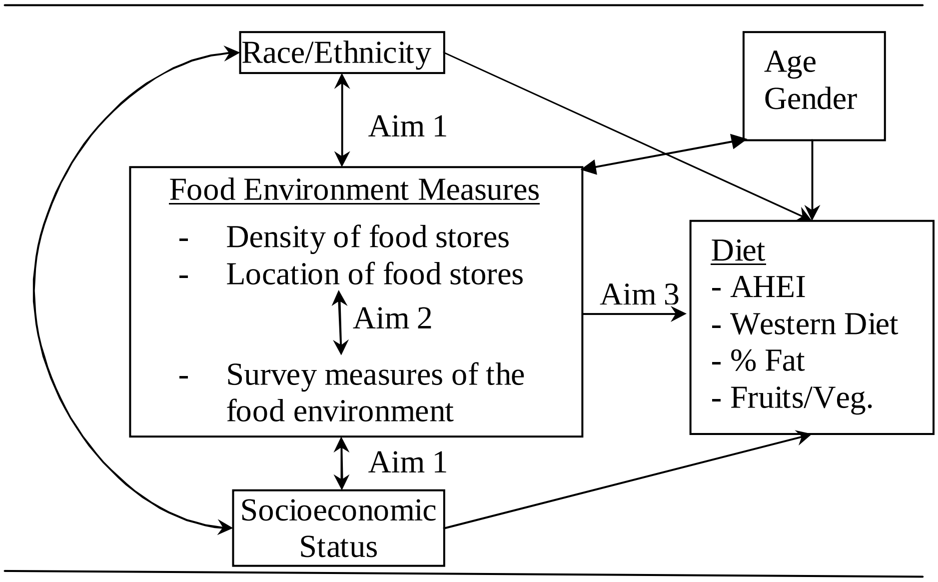
When comparing supermarkets with neighborhood grocers in 1986, Sallis et al found that supermarkets had twice the number of heart healthy foods compared to neighborhood grocers (50). The significance of this study in terms of how these environmental factors may contribute to health disparities was reaffirmed almost 15 years later by a study conducted by Morland et al. in 2001 that concluded that communities that were predominantly black may not have equal access to supermarkets (4). The authors found that there were four times the number of supermarkets in predominantly white census tracts (< 20% black residents) compared to predominantly black census tracts (>80% black resident). Additionally, the authors suggested that since fewer households in black neighborhoods have access to private transportation, these residents may experience more difficulty in obtaining healthy food and achieving a healthy diet.

Sloane et al inventoried selected markets in areas of high African-American concentration and wealthier areas with fewer African Americans in the Los Angeles metropolitan area (7). Echoing the results of the 1986 Sallis study, this study found that fresh produce, low-fat and nonfat dairy, soy milk, tofu, whole grain pasta and breads, and low-fat meat and poultry items were significantly less available in African American areas. The authors speculated that the health disparities experienced by African-American communities have origins that extend beyond the health delivery system and individual behaviors and that adherence to the healthy lifestyle associated with low chronic disease risk is more difficult in resource-poor neighborhoods.

Similarly, Horowitz found that healthy foods recommended for diabetics were less available in grocers in minority areas, although those that were available were slightly less expensive (14). In their study, residents of a predominantly black area in New York were more likely than residents of an adjacent predominantly white area to have stores on their block that did not stock healthy foods (50% vs. 24%). Recently, Zenk et al reported that in metropolitan Detroit the most impoverished neighborhoods in which most African Americans resided were further from the nearest supermarket than were White neighborhoods. The study concluded that racial residential segregation disproportionately places African Americans in more-impoverished neighborhoods in Detroit and reduced access to supermarkets (17). Other studies evaluating the cost of market baskets in different neighborhoods and types of stores have continued to echo these findings (15).

This inequity in the spatial allocation of resources has been linked with diet quality in several studies. Morland reported in 2002 that black Americans' fruit and vegetable servings per day increased by 32% for each additional supermarket in the census tract (relative risk [RR] = 1.32; 95% confidence interval [CI] = 1.08, 1.60) while white Americans' fruit and vegetable intake increased by 11% with the presence of 1 or more supermarket (RR = 1.11; 95% CI = 0.93, 1.32)(5). The proportion of blacks meeting dietary recommendations for fat intake was 25% higher among those living in areas with at least one supermarket. Similarly, Laraia et al in 2004 reported that pregnant women living greater than 4 miles from a supermarket were half as likely to have a healthy diet as women living within 2 miles of a supermarket (9). In a natural experiment, an area of a British city experienced a sudden and significant change in its food retail access as a result of the opening of a large food superstore. Previously, 70-90% of residents in the area did not have retailers that sold a variety of fresh fruits and vegetables within 500 meters of their homes, considered a reasonable walking distance. A before and after survey of 600 people found that people with the worst diets, those who consumed <2 fruits and vegetables a day, increased consumption by 34% after the store opening (11;51). Zenk et al also indicated in 2005 that Detroit women shopping at supermarkets and specialty stores consumed fruit and vegetables more often, on average, than those shopping at independent grocers (18). Limitations of the current literature are apparent in that most analyses are based on a relatively incomplete assessment of the food environment with studies surveying only supermarkets, grocers, and convenience stores to the exclusion of other food sources in areas including fruit and vegetable stores, bakeries, etc. that may offer healthy options in the absence of supermarkets. The current literature with few exceptions also has mainly focused only on small geographic areas effectively limiting generalizability. Measurement issues including the most appropriate way of representing the local food environment and how the environment is related to what people report is available in their neighborhoods have also been neglected. Measuring the food environment by only noting the presence or absence of types of stores as the majority of studies in this area do has important limitations as these measures are only crude proxies for what is actually available. Using survey based measures to represent the food environment may more adequately represent what is available in small areas. The scope of the current literature leaves an abundance of unanswered questions that this research is intended to address as illustrated in the following conceptual diagram including if a diversity of smaller stores make up for the lack of supermarkets in neighborhoods and if the local food environment in its entirety is associated with sociodemographic characteristics of neighborhoods (Aim 1); if the presence of a supermarket or many smaller stores is related to better self reported

Figure 1.2: Conceptual Diagram



availability of healthy products (Aim 2); and if survey based measures of the local food environment which may tap into different constructs than the presence of absence of a certain type of store is associated with dietary patterns (Aim 3).

As illustrated in the conceptual diagram, Aim 1 will examine associations of both the racial/ethnic and socioeconomic composition of neighborhoods with the location of the different types of food stores. Bidirectional arrows are shown in the figure to graphically represent unmeasured societal and economic factors that may dictate what stores are available in neighborhoods (i.e. area purchasing power, prejudices, etc. (21;52)) and where racial/ethnic groups live (i.e. residential segregation, selective mortgage lending practices, etc.). Aim 2 will examine the interrelation of GIS derived densities of stores with survey based measures of the local food environment. Aim 3 postulates that the local food environment measured by various methods will directly affect (unidirectional arrow) diet quality. Socioeconomic status and race/ethnicity are both expected to be confounders of the relationship (diet quality and food environment measures are both patterned by these personal characteristics). Age and gender are also potentially associated with survey based measures and have been shown to be associated with dietary patterns so accordingly these variables will also be controlled for in analyses. Associations will be examined qualitatively by age (<65 vs. 65 and over), sex, race/ethnicity, per capita income (dichotomized at median), and time spent in neighborhood (dichotomized at median).

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Chapter 2: Measuring the Local Food Environment Using Existing Data: Reliability, Stability, & Associations with Sociodemographic Characteristics

2.1 Introduction

Recent evidence from epidemiologic studies suggests that neighborhood characteristics are related to health after taking into account individual-level confounders (1;2). Many factors have been proposed to explain neighborhood health effects including physical access to the resources necessary to develop and maintain healthy lifestyles. In particular, neighborhood factors related to access to healthy foods, sometimes termed the "local food environment", have received increasing attention (3-6) due in part to the high and increasing prevalence of obesity and overweight (7). Although scientific proof of a causal effect of the local food environment on individual diet is difficult to obtain, local food environments and residents' diets have been linked in observational studies (8-10). Preliminary data from natural experiments also suggests that changes in the local food environment result in changes in people's diets (11).

The presence of strong residential segregation by income and race/ethnicity in the United States(12;13) also suggests that the local food environment may contribute to socioeconomic and race/ethnic differences in health. Healthy foods may be less available, and relatively more costly, in poor and minority neighborhoods compared to wealthier and white neighborhoods. The combination of the migration of supermarkets, which often offer nutritious foods at lower costs (3;14-19), from urban to suburban areas and the lack of transportation among the urban poor may contribute to health disparities in heart disease, obesity, and diabetes. Nevertheless, there is still limited evidence of how the local food environment varies across neighborhoods and the extent to which it is associated with features of neighborhoods such as racial/ethnic composition (3;6). Furthermore, published evidence focuses almost exclusively on a limited number of stores (supermarkets, convenience stores, and small grocers) omitting other food establishments that may be present in neighborhoods. Also important but not explored is how characterizations of the food environment may vary by different data sources and at different time points. Using data from three large and ethnically diverse areas in the United States this chapter investigates differences in several different aspects of the local food environment across neighborhoods with different racial/ethnic and socioeconomic composition. The reliability and stability of measures of the local food environment using different data sources and time points is also investigated.

2.2 Associations of neighborhood characteristics with the location and type of food stores

2.2.1 Methods

The study areas included 75 census tracts in Forsyth County, NC, 276 census tracts in parts of Baltimore City and Baltimore County MD, and 334 census tracts in Northern Manhattan and the Bronx NY. These areas correspond to neighborhoods from which participants in a large multiethnic study of atherosclerosis (the Multiethnic Study of Atherosclerosis, MESA) were sampled(20). Information on food establishments located in the study areas was purchased from InfoUSA Inc, a proprietary information service, in November of 2003. InfoUSA offers commercial databases on businesses with information regarding business openings and closings (obtained through US department of Labor, phone books, county offices, National Change of Address listings through the postal service, and utility companies) updated on a weekly basis. Selected characteristics of the businesses are verified monthly by telephone interviews. Businesses may be excluded from the directory on request with refusal rates averaging 12% (M. Dinarte, InfoUSA representative, personal communication, September 2004). Standard Industrial Classification (SIC) codes were assigned to each business by InfoUSA in-house using standardized criteria and information obtained and verified from the businesses. SIC codes are standardized four digit codes developed and updated in 1987 by the Office of Budget and Management used by government agencies for the purposes of monitoring economic activity and business patterns in the US(21). SIC codes were supplemented with an additional two digit code developed by InfoUSA to further detail types of businesses. All establishments classified as retail food (SIC Major Group 54) and liquor stores (SIC 5912) were obtained from these commercial lists. The information obtained on each establishment included name, address, SIC code, number of annual employees, annual sales volume, approximate square footage, and type of business (branch, single location, franchised, headquarters, etc.). All locations were geocoded to the 2000 Census.

The three study areas included a total of 3337 food and liquor stores. These were classified into the following categories using the InfoUSA SIC codes: grocers and supermarkets (541101, 541104-541106); convenience stores (541102, 541103); meat and fish markets (5421, 549907, 549911); fruit and vegetable markets (543101, 543102, 543103, 549933); bakeries (5461); natural food stores (549901, 549909, 549935); specialty food stores (SIC 549910, 549912, 549914, 549916-549921, 559923, 549926-549928, 549930, 549937); and liquor stores (SIC 5912). Manufacturing plants and corporate headquarters as identified by the InfoUSA database were excluded from analysis due to their inaccessibility to the public. Following prior work (14;16), supermarkets were differentiated from grocers based on chain name recognition and/ or an annual payroll of greater than 50 employees. Information on census tract characteristics including population, land area, racial/ethnic composition, and tract median household income was obtained from the Year 2000 US Census. Census tracts with greater than 60% of the residents in any particular racial/ethnic group were defined as predominantly non-Hispanic white, predominantly non-Hispanic black or predominantly Hispanic areas. Tracts that did not fall into any of these categories were classified as racially mixed areas.

Census tract and food store characteristics were compared across study areas and across categories of racial/ethnic composition using chi-squared tests or ANOVA. Poisson regression was then used to examine associations of tract racial/ethnic composition with the types of stores present. The number of the various types of stores in each tract was modeled as a function of the census tract race/ethnic composition, the area of the tract in square miles, and the population size as an offset as shown in Equation 2.1.

Equation 2.1 $\log_e(\text{stores}_i) = \beta_0 + \sum_{k=1}^{3} \beta_k (\text{race}_i) + \beta 4(\text{area}_i) + \log_e(\text{pop}_i)$

where stores = number of each type of food store in the i^{th} census tract

race = dummy variables for the racial composition of the i^{th} tract

= {predominantly black, racially mixed, predominantly Hispanic, predominantly white (referent)}

area = area of the i^{th} tract in square miles

pop = population of the i^{th} tract

Because the socioeconomic composition of tracts was strongly associated with the ethnic composition of the tract (correlation between % minority and median household income in tracts $\rho = -0.72$ $p<0.0001$), race/ethnic composition was not isolated from socioeconomic composition. However, selected analyses were repeated for categories of census tract median household income. Models were run separately for each type of store using SAS GENMOD(22). Analyses were also run separately by study site due to the different ethnic composition of the areas and to capture differing patterns in the food store distributions across sites. Models combining all three study areas but adjusting for site were also run excluding predominantly Hispanic areas in New York because of the absence of these tracts in the other study sites. Interactions between site and neighborhood racial composition as previously described were also tested for in the overall model.

2.2.2 Results

Table 2.1 presents characteristics of the census tracts and the food environment in each site. North Carolina is the largest of the study sites in terms of area covering almost 410 square miles, with an average of 747 people per square mile with the majority of neighborhoods being predominantly white. The Maryland study area covers over 240 square miles with 4127 people per square mile and almost equal numbers of predominantly black and predominantly white neighborhoods. New York is the most densely populated area with 65230 people per square mile in an area of 26 square miles and is also the most ethnically diverse. Tract median household income is highest in North Carolina and lowest in New York. The New York site consisted of only urban tracts. The Maryland and North Carolina sites included a small number of predominantly rural tracts (less than 50% of the population in the census tract living in an urban area as defined by the US Census, < 1% in Maryland and 4% in North Carolina).

The number of food stores per population is fairly constant across the three sites (8-10 per 10,000 people). However, in New York there are significantly more food stores per square mile than in Maryland or North Carolina (65 stores/mi^2 vs. 1-3 stores/mi^2), reflecting the much higher population density in New York. Despite similarities in the total number of stores per population, the distribution of the types of stores varied across the three sites. Grocers are the most common type of store in New York and Maryland, and convenience stores are the most common type of store in North Carolina. North

Table 2.1: Characteristics of census tracts included in the analyses by site

	MD	NC	NY	P-value*
Number of Tracts	276	75	334	-
Total Area, square miles	241.5	409.6	26.0	-
Median Tract Population	3341	3779	4629	<0.0001
(Q1,Q3)	(2365-4522)	(2684-5247)	(2686-7091)	
Median Household Income	37,758	41,579	25,063	0.005
(Q1,Q3)	(26,530-49,270)	(30,230-51,149)	(18,207-38,446)	
Tract Racial/Ethnic Composition				
% Pred White Tracts	41.3	64.0	19.5	
% Pred Black Tracts	47.1	16.0	13.5	
% Hispanic Tracts	-	-	34.1	
% Mixed Tracts	11.6	20.0	32.9	<0.0001
Number of Food Stores	821	286	1753	-
Stores Per 10,000 People	8	9	10	0.2
Stores Per Sq Mile	3	1	67	<0.0001
Distribution of Stores (%)				
Grocers	37.0	22.4	52.3	
Supermarkets	10.4	13.3	5.0	
Convenience Stores	15.6	40.6	8.2	
Meat & Fish Markets	11.7	4.9	11.1	
Fruit & Veg Markets	3.8	1.8	5.7	
Bakeries	15.7	9.8	11.8	
Natural Food Stores	4.0	3.9	3.8	
Specialty Stores	2.1	3.5	2.3	<0.0001
Number of Liquor Stores	259	18	200	-
Stores Per 10,000 People	3	1	1	<0.0001
Stores Per Sq Mile	1	0	8	<0.0001

Q1 - 25th percentile Q3 - 75th percentile

*P-value for differences across sites from ANOVA (for means) or chi square tests (for proportions)

Carolina neighborhoods also have fewer meat and fish markets, fruit and vegetable markets, and bakeries than the other two study sites. Natural food stores are equally common across the three study sites. Maryland neighborhoods had three times more liquor stores per 10,000 people than the other two sites.

Table 2.2 shows selected census tract characteristics and types of stores by census tract racial/ethnic composition for each site. Predominantly black and Hispanic neighborhoods had lower median incomes and proportionately more people without a vehicle than predominantly white census tracts. The total number of stores per 10,000 population was generally similar across categories, although predominantly white areas generally had slightly lower numbers of stores per 10,000 population possibly reflecting the larger sizes of stores in these areas (19% of stores in predominantly black areas are 2500 square feet or more compared to 42% of stores in predominantly white areas). The types of stores present differed significantly across categories of race/ethnic composition ($p < 0.001$ in all sites). In all three sites, the percent of stores that are grocers was higher in predominantly minority than in predominantly white census tracts. In contrast, the percent of stores that are supermarkets was much higher in predominantly white areas. Natural food stores and specialty food stores are also more common in predominantly white neighborhoods than in predominantly minority ones. Differences in other types of stores were not always consistent across sites: convenience stores are more common in minority neighborhoods in New York, but not in Maryland or North Carolina; meat and fish markets are more common in minority neighborhoods in North Carolina but not at the other two study sites; fruit and vegetable markets and bakeries are less common in minority neighborhoods in New York and Maryland but not in North Carolina. Differences between low income and high income neighborhoods were analogous to those observed between minority and predominantly white neighborhoods (not shown). On average, there were no clear differences in the number of liquor stores per 10,000 population across categories of neighborhood ethnic composition.

Ratios of the number of stores by race/ethnic composition are shown in Table 2.3. These correspond to the ratio of the number of stores per population in each category vs. the reference category (predominantly white tracts), adjusted for census tract size and site where appropriate. Site-adjusted estimates are not shown for predominantly Hispanic

Table 2.2: Selected tract characteristics by site & tract race/ethnic composition

	Pred Black	Pred Hispanic	Racially Mixed	Pred White	P-Value*
MD Tracts					
Median Household Income	27,384	-	42,732	48,496	<0.0001
Households without a vehicle (%)	39.4	-	22.4	12.3	<0.0001
Number of Food Stores	377	-	133	311	-
Stores Per 10,000 Population	8	-	10	8	0.09
Stores Per Sq Mile	7	-	6	2	0.004
% of Stores > 2500 sq ft	18	-	35	46	<0.0001
Types of Stores (%)					
Grocers	54.6	-	21.8	21.5	
Supermarkets	6.9	-	12.0	13.8	
Convenience Stores	14.9	-	18.1	15.4	
Meat & Fish Markets	9.8	-	16.5	11.9	
Fruit & Veg Markets	2.7	-	6.0	4.2	
Bakeries	8.5	-	16.5	24.1	
Natural Food Stores	1.6	-	8.3	5.1	
Specialty Stores	1.1	-	1.0	3.9	<0.0001
Number of Liquor Stores	133	-	37	89	-
Stores Per 10,000 People	3	-	3	2	0.04
Stores Per Sq Mile	2	-	2	1	<0.0001
NC Tracts					
Median Household Income	19,321	-	30,230	48,815	<0.0001
Households without a vehicle (%)	32.7	-	15.2	4.7	<0.0001
Number of Food Stores	39	-	67	180	-
Stores Per 10,000 Population	11	-	11	9	0.6
Stores Per Sq Mile	3	-	1	1	<0.0001
% of Stores > 2500 sq ft	28	-	39	37	0.002
Types of Stores (%)					
Grocers	30.8	-	32.8	16.7	
Supermarkets	5.1	-	6.0	17.8	
Convenience Stores	33.3	-	35.8	43.9	
Meat & Fish Markets	18.0	-	3.0	2.8	
Fruit & Veg Markets	2.6	-	0.0	2.2	
Bakeries	7.7	-	14.9	8.3	
Natural Food Stores	0.0	-	3.0	5.0	
Specialty Stores	2.6	-	4.5	3.3	0.0005
Number of Liquor Stores	0	-	7	11	-
Stores Per 10,000 People	0	-	1	1	0.03
Stores Per Sq Mile	0	-	< 1	< 1	0.02

Table 2.2 Cont'd	Pred Black	Pred Hispanic	Racially Mixed	Pred White	P-Value*
NY Tracts					
Median Household Income	21,480	21,209	25,114	71,283	<0.0001
Households without a vehicle (%)	77.4	78.3	71.2	64.5	<0.0001
Number of Food Stores	152	810	475	316	-
Stores Per 10,000 Population	9	13	10	8	0.2
Stores Per Sq Mile	48	116	42	69	<0.0001
% of Stores > 2500 sq ft	18	13	20	40	<0.0001
Types of Stores (%)					
Grocers	55.9	59.8	55.2	26.9	
Supermarkets	6.6	2.5	5.3	10.1	
Convenience Stores	10.5	9.4	8.8	2.9	
Meat & Fish Markets	11.2	11.7	11.0	9.5	
Fruit & Veg Markets	4.0	5.3	4.8	8.5	
Bakeries	8.6	9.1	9.1	24.4	
Natural Food Stores	3.3	1.9	3.8	9.2	
Specialty Stores	0.0	0.4	2.1	8.5	<0.0001
Number of Liquor Stores	19	72	49	60	-
Stores Per 10,000 People	1	1	1	2	0.3
Stores Per Sq Mile	6	10	4	13	0.001

*P-value for differences across categories of tract racial/ethnic composition from ANOVA (for means) or chi square tests (for proportions)

tracts because these tracts were only present in the New York site. Interactions of racial/ethnic composition of tracts with site were not statistically significant at the 0.05 level. Overall, predominantly minority and racially mixed neighborhoods had significantly more grocers than predominantly white neighborhoods (site-adjusted store per population ratios (SR) and 95% confidence limits (CL): 2.7 CL 2.2-3.2 for predominantly black tracts and SR 2.2 CL 1.9-2.7 for mixed tracts). In contrast, supermarkets were less common in predominantly minority and racially mixed neighborhoods (SR 0.5 CL 0.3-0.7 for predominantly black tracts and SR 0.7 CL 0.5-1.0 for mixed tracts). In general, predominantly black neighborhoods also had less fruit and vegetable markets (except in North Carolina), bakeries, specialty stores, and natural food stores than predominantly white neighborhoods. In New York, convenience stores were significantly more common in predominantly minority and racially mixed neighborhoods but no differences were observed for the other sites. Meat and fish markets were significantly more common in mixed neighborhoods in Maryland and Hispanic

Table 2.3: Ratios of food stores per population (95% confidence limits) by tract racial/ethnic composition and site *

	Type of Store								
	Grocers	Supermarkets	Convenience Stores	Meat & Fish Markets	Fruit & Veg Markets	Bakeries	Natural Food Stores	Specialty Food Stores	Liquor Stores
MD									
Racially Mixed	1.2	1.2	1.6	1.8	1.9	0.9	2.3	0.3	1.3
	(0.8-1.8)	(0.7-2.1)	(0.9-2.5)	(1.0-3.0)	(0.8-4.6)	(0.6-1.6)	(1.1-5.0)	(0.0-2.1)	(0.9-1.8)
Pred Black	1.7	0.5	1.0	0.7	0.7	0.4	0.4	0.3	1.1
	(1.3-2.2)	(0.3-0.9)	(0.7-1.5)	(0.5-1.2)	(0.3-1.5)	(0.3-0.6)	(0.1-1.0)	(0.1-1.0)	(0.9-1.5)
NC									
Racially Mixed	2.8	0.3	0.9	0.9	0.0	1.6	0.5	1.3	1.6
	(1.6-5.2)	(0.1-0.9)	(0.6-1.5)	(0.2-4.7)	(0.0-0.0)	(0.7-3.7)	(0.1-2.4)	(0.3-5.4)	(0.6-4.1)
Pred Black	3.0	0.2	0.9	3.2	2.6	0.6	0.0	0.6	0.0
	(1.4-6.5)	(0.1-1.0)	(0.5-1.6)	(0.9-11.5)	(0.2-32.3)	(0.2-2.2)	(0.0-0.0)	(0.1-5.5)	(0.0-0.0)
NY									
Racially Mixed	2.5	0.6	3.7	1.4	0.7	0.5	0.5	0.3	0.7
	(1.9-3.2)	(0.4-1.1)	(1.8-7.7)	(0.9-2.2)	(0.4-1.2)	(0.3-0.7)	(0.3-0.9)	(0.2-0.6)	(0.5-1.0)
Pred Black	2.5	0.8	4.4	1.4	0.6	0.4	0.4	0.0	0.8
	(1.9-3.4)	(0.4-1.6)	(2.0-10.1)	(0.8-2.6)	(0.2-1.3)	(0.2-0.8)	(0.2-1.1)	(0.0-0.0)	(0.5-1.3)
Pred Hispanic	3.7	0.4	5.5	2.0	1.0	0.6	0.3	0.1	0.8
	(3.0-4.7)	(0.2-0.7)	(2.8-11.0)	(1.3-3.1)	(0.6-1.7)	(0.4-0.8)	(0.2-0.6)	(0.0-0.2)	(0.5-1.1)
Overall (adjusted for site)									
Racially Mixed	2.2	0.7	1.5	1.4	0.9	0.6	0.8	0.4	0.9
	(1.9-2.7)	(0.5-1.0)	(1.1-1.9)	(1.0-2.0)	(0.5-1.4)	(0.5-0.8)	(0.5-1.2)	(0.2-0.7)	(0.7-1.2)
Pred Black	2.7	0.5	1.2	1.0	0.6	0.4	0.3	0.2	1.0
	(2.2-3.2)	(0.3-0.7)	(0.9-1.6)	(0.7-1.4)	(0.3-1.1)	(0.3-0.5)	(0.2-0.6)	(0.1-0.5)	(0.3-1.3)
P-values for Interactions**	0.2407	0.4201	0.0720	0.2269	0.5149	0.1909	0.2384	0.3991	0.1061

*Models adjusted for tract population and size. Referent: Predominantly white census tracts **Interaction between race/ethnicity & site neighborhoods in New York. They were also more common in predominantly black than in predominantly white neighborhoods in North Carolina, but confidence intervals on this estimate were wide. Predominantly minority and racially mixed neighborhoods did not differ significantly from white neighborhoods in terms of liquor stores. Low income neighborhoods had four times as many grocers per population as the wealthiest neighborhoods (SR 4.3 CL 3.6-5.2) and half as many supermarkets (SR 0.5 CL 0.3-0.8) (Table 2.4). Fruit and vegetable markets, bakeries, natural food stores, and specialty stores were also less common in low income neighborhoods, although confidence limits for some estimates overlapped 1. In contrast, meat and fish markets were more common in low income neighborhoods. Liquor stores were also more common in the poorest than in the wealthiest neighborhoods (SR 1.3 CL 1.0-1.6).

2.2.3 Discussion

These results show that neighborhoods differ in the types of food stores that are available, and that the location of food stores is associated with neighborhood race/ethnic and socioeconomic composition. Predominantly white and wealthier areas were found to have more supermarkets than predominantly minority and poorer areas after accounting for population and geographic size. In contrast, small grocers were more common in predominantly minority areas and in poorer areas. In general, poorer areas and non-white areas also tended to have less fruit and vegetable markets, bakeries, specialty stores, and natural food stores. Liquor stores were more common in poorer than in wealthier areas.

In a study of four areas (of which one was Forsyth County North Carolina, also included in these analyses) Morland et al(3) also found that significantly more supermarkets were located in white compared to black neighborhoods and that smaller grocers were more common in black neighborhoods. Sloane et al(23) also reported a higher proportion of convenience stores and small grocers in predominantly minority communities than in predominantly white neighborhoods. To the extent that supermarkets offer a broader choice of affordable healthy foods, these patterns could have consequences for the diets of residents.

By examining a range of different types of stores, these results show that the pattern is significantly more complex than simply less supermarkets and more small grocery stores in predominantly minority neighborhoods as described in previous studies. Minority and poor neighborhoods also had proportionately less bakeries, natural food stores, and specialty stores. Predominantly black neighborhoods had less fruit and vegetable markets in two of the three sites. In contrast meat and fish markets were common in minority neighborhoods in New York and North Carolina and in poor neighborhoods generally. Convenience stores were more common in minority neighborhoods in New York. In general the food environment appears to be less diverse in poor and minority neighborhoods, compared to wealthier and predominantly white neighborhoods.

Clearly, the food store environment differs across the three sites studied and also differs in complex ways across neighborhoods within sites. The types of stores present are obviously a limited measure of the availability of healthy foods, since even the same "type" of store may offer very different food choices in different types of neighborhoods. A recent study by Horowitz et al found that only 18% of bodegas, or small grocers, in a minority neighborhood carried a selection of healthy foods compared to 58% of those in a predominantly white area. Thus, more detailed assessment of actual food offered may show even greater differences in the local food environment than those suggested by differences in the simple counts of different types of stores.

The dietary consequences of neighborhood differences in food stores depends on multiple factors including the types of foods available at the stores and the extent to which residents rely on local stores for shopping. If small grocers do indeed offer less

Table 2.4: Ratios of food stores per population (95% confidence limits) by tertile of tract median income *

Type of Store	Lowest Income Tracts (≤ $25,000)		Middle Income Tracts ($25,001-$45,000)	
Grocers	4.3	(3.6-5.2)	2.8	(2.3-3.3)
Supermarkets	0.5	(0.3-0.8)	0.8	(0.6-1.0)
Convenience Stores	2.4	(1.8-3.2)	1.6	(1.2-2.1)
Meat & Fish Markets	2.1	(1.5-2.8)	1.5	(1.1-2.1)
Fruit & Veg. Markets	0.9	(0.6-1.4)	0.8	(0.5-1.2)
Bakeries	0.6	(0.5-0.8)	0.9	(0.7-1.1)
Natural Food Stores	0.3	(0.2-0.5)	0.5	(0.3-0.8)
Specialty Food Stores	0.2	(0.1-0.4)	0.5	(0.3-0.8)
Liquor Stores	1.3	(1.0-1.6)	0.9	(0.7-1.2)

*Models adjusted for census tract population, site, and tract area size.
Referent: Highest income census tracts (median income 45,001-175,000)

healthy foods than supermarkets and other types of stores are not present (as suggested by this data), residents of poor and minority neighborhoods who depend on local stores as their main source of food may be nutritionally disadvantaged. However, it is important to emphasize that the relationship between type of store and products offered is by no means fixed. It is perfectly plausible that a multiplicity of varied small stores can offer the range of food products necessary for a healthy diet. There are also important trade offs between large supermarkets (which often require large parking lots) and small stores in terms of automobile traffic and consequences for neighborhood walkability and street life (including social interactions between neighborhoods), all of which have may have health consequences. In the US context, the presence of a supermarket may be an adequate marker for availability of affordable healthy foods. However, it does not necessarily follow that improving the food environment of disadvantaged communities requires only increasing the number of large supermarkets.

We relied on SIC codes, a standard classification system, to classify businesses into store types. Although any store classification scheme has its limitations, the use of a standard system allows replication across studies. There is no doubt that some misclassification is inevitable; however, there is no reason to believe that misclassification differed systematically across neighborhoods in ways that could have generated the patterns that we observed. Unfortunately, neither SIC codes, nor the more recent standard classification system, the North American Industry Classification System codes, distinguish supermarkets from other grocers. Criteria for the classification of supermarkets was based on prior work(14;16). In sensitivity analyses, a comparison of this supermarket classification scheme to that used by Kaufman (24) found that only 8% of businesses were classified differently. Thus theses results are likely to be robust to different approaches to classifying supermarkets.

Another limitation of using lists of businesses for these analyses is that they do not capture informal food sources such as street vendors and roadside stands. These sources may be important in certain types of neighborhoods. It was also not possible to capture qualitative differences in the foods offered by the same type of store in different contexts with this data source. For example, a convenience store in New York could offer a plethora of healthful options compared to a small grocer in North Carolina. The use of a standardized data sources on businesses across large areas necessarily implies a lack of detailed, qualitative information. For these reasons, large studies like these need to be complemented with more detailed in depth assessments of the local food environment in these areas.

2.3 Reliability of InfoUSA Data in Characterizing the Food Environment

An important concern in studies that investigate the local food environment using existing commercial data sources is the reliability of the data sources used. Characterizations of the food environment may vary by different data sources and this may significantly affect the validity and interpretation of study results. Although InfoUSA is a commercial database established for marketing purposes rather than data collected for research purposes, no better source of data exists and primary data collection across the broad study areas is not feasible. In spite of some under-representation of stores (approximately 12% of stores are not listed), findings from this analysis are consistent with those of researchers using other sources of data (3;6). Nevertheless, empirical studies that assess the reliability of these data sources are needed. In the absence of a true "gold standard" validity cannot be assessed. However, it is possible to assess the reliability of measures constructed from InfoUSA by comparing them to measures derived from different data sources. In order to assess the reliability of InfoUSA data, measures to characterize the location and type of stores in the local food environment derived from InfoUSA were compared with data from County Business Patterns (CBP), another data source compiled by US government agencies for economic censuses.

2.3.1 Methods

County Business Patterns is a series published annually since 1964 collected by the US Census Bureau that provides national economic data for the entire universe of businesses (25). Most US economic activity is represented in this series tabulated by industry as defined in the North American Industry Classification System (NAICS) except for activities of self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. County Business Patterns is compiled from the Business Register, the Census Bureau's file of all known single and multi-establishment companies. The Annual Company Organization Survey and quinquennial Economic Censuses provide individual establishment data for multi-location firms. Data for single-location firms are obtained from various Census Bureau programs and records including the Economic Censuses, the Current Business Surveys, the Annual Survey of Manufactures, the administrative records of the Internal Revenue Service (IRS), the Social Security Administration (SSA), and the Bureau of Labor Statistics (BLS).

The number of food stores (NAICS codes 445110-445299, 447110, 452910) and employment size class at the 5 digit zip code level for 2003 was downloaded from the US Census Bureau County Business Patterns website for each of the 76 zip codes in the MESA Study Areas. Zip codes served as crude proxies for residential neighborhoods due to limitations imposed by CBP in which zip codes are the smallest available geographic unit. To ensure comparability to CBP data, supplemented SIC codes for businesses in 2003 from InfoUSA were recoded to NAICS codes to match CBP as closely as possible. Most food industries were revised or new categories created under the newer NAICS system with only parts of various SICs contributing to the NAICS categories as shown in Table 2.5. Because of these many inherent incomparabilities between the two systems only total stores, supermarket, and all other stores were explored. Grocery stores (SIC 541101, 541104-541106) with an annual payroll of greater than 50 employees were classified as supermarkets. InfoUSA data was then aggregated up to the zip code level to match CBP.

Intraclass correlation coefficients (ICCs) and 95% confidence intervals were calculated at the zip code level. A value of 1 for the ICC indicates perfect agreement between CBP and InfoUSA in that all of the variation in the numbers of stores is between zip codes rather than between the data sources within zip codes(26). If the two data sources do not comparably measure stores in the zip code then most of the variation would be between the two data sources rather than between zip codes (i.e. ICC = 0). Since identical years of data were extracted from both data sources, adjustments for population and area size were not performed. In a second stage of analysis, ICCs were

Table 2.5: 1987 SIC Codes Matched to 1997 NAICS Codes

1987 SIC	1987 US SIC Description	1997 NAICS	Industry Change[+]	1997 NAICS U.S. Description
*5411	Grocery Stores		N	
	Convenience Stores with Gas	44711		Gasoline Stations with Convenience Stores (pt)
	Supermarkets & Grocery Stores with Little General Merchandise	44511		Supermarkets & Other Grocery (except Convenience) Stores
	Supermarkets & Grocery Stores with Substantial General Merchandise	45291		Warehouse Clubs & Superstores (pt)
	Convenience Stores without Gas	44512		Convenience Stores
*5421	Meat & Fish (Seafood) Markets		R	
	Freezer Provisioners	45439		Other Direct Selling Establishments (pt)
	Meat Markets	44521		Meat Markets (pt)
	Fish & Seafood Markets	44522		Fish & Seafood Markets
5431	Fruit & Vegetable Markets	44523	E	Fruit & Vegetable Markets
*5461	Retail Bakeries		R	
	Doughnut Shops, Pretzel Shops, Cookie Shops, Bagel Shops, & Other Such Shops that Make & Sell for Immediate Consumption	722213		Snack & Nonalcoholic Beverage Bars (pt)
	Bakeries That Make & Sell at the Same Location	311811		Retail Bakeries
	Sales Only of All Other Baked Goods	445291		Baked Goods Stores
*5499	Miscellaneous Food Stores		R	
	Poultry & Poultry Products	44521		Meat Markets (pt)
	Food Supplement Stores	446191		Food (Health) Supplement Stores
	All Other Miscellaneous Food Stores	445299		All Other Specialty Food Stores (pt)
5451	Dairy Products Stores	445299		All Other Specialty Food Stores (pt)

[+]E-Existing industry without significant change from SIC; R-Revised; N-New Industry

* = indicates only part of the SIC is contributing to the NAICS category on that line; part defined in parentheses in the 1987 SIC description

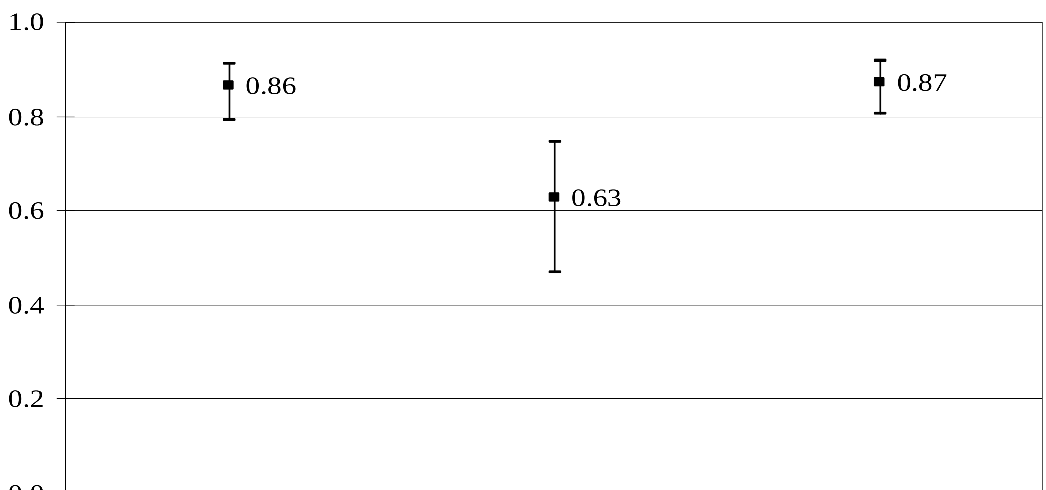
(pt)= component is mixed parts from other SICs to form the NAICS industry

Excerpt from http://www.census.gov/epcd/naics/nsic6.htm calculated stratified by site, zip code racial/ethnic composition, and zip code socioeconomic composition (using site specific categories based on median household income to explore agreement across demographic characteristics of areas.

2.3.2 Results

ICCs and confidence intervals for all three sites pooled are shown in Figure 2.1. 86% of the variation in the number of stores reported by CBP and InfoUSA is between zip codes (ICC = 0.86 [95% CI 0.79-0.91]). There was more variation between the data sources for supermarkets (ICC=0.63 [0.47-0.75]). Overall agreement for all stores not classified as supermarkets was very high (ICC=0.87 [0.81-0.92]). Very small sample sizes in secondary analyses limited the interpretation of stratified statistics; however, in general, overall agreement, agreement for supermarkets, and agreement for all other stores in the zip codes was lower in predominantly minority neighborhoods, although confidence intervals overlapped with those for ICCs in predominantly white and racially mixed areas. ICCs did not differ across categories of socioeconomic composition. Agreement also varied somewhat by site: the highest agreement for all stores was observed in the North Carolina site ICC=0.96[0.89, 0.99], followed by the New York site

Figure 2.1: Comparison of Types of Food Stores in Zip Codes: InfoUSA vs. CBP



	All stores	Supermarkets	All other stores
ICC	0.86	0.63	0.87
Lower	0.79	0.47	0.81
Upper	0.91	0.75	0.92

ICC=0.80[0.62-0.90]. The poorest agreement was observed at the Maryland site ICC=0.63 [0.35, 0.80].

2.3.3 Discussion

When comparing the commercial database InfoUSA to that compiled by government sources in CBP there was high agreement between the two data sources. This high level of agreement suggests that InfoUSA is a reasonably reliable data source for characterizing the food environment in these series of studies. Agreement was generally very high for all non supermarkets overall and lower for supermarkets. Inconsistencies between NAICS and SIC in the coding of subtypes of stores prevented the exploration of agreement by store type. In spite of difficulties in converting SIC to NAICS codes, most importantly, InfoUSA captured the presence of the number establishments very well in the study areas. Differences in agreement by zip code racial composition and socioeconomic composition were not large suggesting that these differences are unlikely to significantly affect results of studies relating the local food environment to the socioeconomic or race ethnic composition of areas.

Disagreement between the data sources is most likely attributable to two main sources. Firstly, the data sources are not completely identical in time sequence. InfoUSA data only includes establishments present up to the month of August in 2003 while CBP represents all businesses present during the year 2003. Secondly, disagreement is also likely caused by inherent differences in the classification methods used by the standard NAICS system and the system created by InfoUSA. It is likely that commercial databases will continue to be used in research because of their utility in the examination of differences in the local food environment (and their potential health consequences) across large areas in a systematic fashion. While neither dataset in this analysis is a gold standard, even moderate agreement suggests that differences in the food environment can be reasonably and reliably measured with existing commercial data.

2.4 Stability of InfoUSA Data over Time

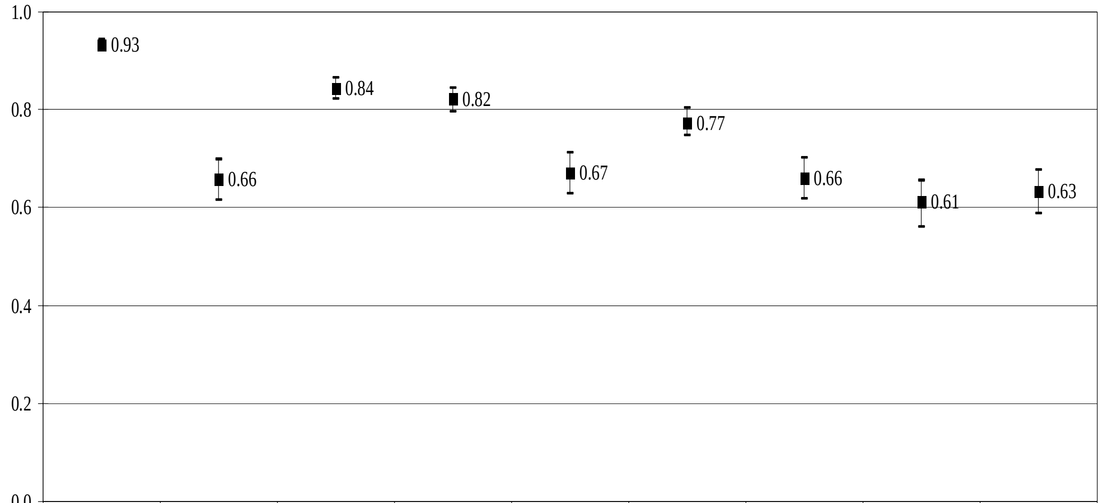
The results of the analyses presented in section 2.1.2 indicate that important differences across neighborhoods exist in the types of food stores available. The results presented in section 2.2.2 indicate that the InfoUSA database is reasonably reliable in characterizing the presence of supermarkets and other stores. An important question is what implications differences in local food environments have for the diet of individuals. Providing answers to this question requires relating the different types of stores to the dietary patterns of individuals. Although two recent studies have shown that the presence or proximity of supermarkets in neighborhoods is associated with the probability of meeting dietary recommendations in certain populations (10;27), there is still very limited data on this question. The last component of this dissertation will relate these characteristics of the local food environment to dietary patterns in individuals from the Multiethnic Study of Atherosclerosis. However while InfoUSA has been shown to be a reliable data source for characterizing the local food environment, the stability of these measures must be considered. Logically, the local food environment may change over time as stores open and close. Assessing how the food environment changes with time is especially important in this project because information used to characterize the local food environment was collected one year after the dietary data to be used in later analysis was collected. Accordingly, exploring agreement between characterizations of the local food environment in adjacent years to determine if the food environment changes significantly is integral to study interpretations.

2.4.1 Methods

Data from InfoUSA Inc. was purchased in August of 2003 and 2004 and classified into the eight types of food stores previously described based on the supplemented Standard Industrial Code provided by the company. All businesses except for liquor stores were included in analysis. For both years of data, the number of stores for each type of store was aggregated up to the census tract level. In a one year period, it is unlikely that the population or the area of the census tracts have changed significantly so that no adjustments for tract size or population were made in this analysis. Demographic information on census tracts was obtained from Census 2000 data.

ICCs and 95% confidence intervals and stratified analyses as in section 2.2.1 were repeated for this aim at the census tract level to assess the agreement between the two years of InfoUSA data.

Figure 2.2: Comparison of Types of Food Stores in Census Tracts: 2003 vs. 2004



	All stores	Supermarkets	Grocer stores	Meat & Fish	Convenience stores	Fruit & Vegetable markets	Bakeries	Speciality	Natural food stores
■ ICC	0.93	0.66	0.84	0.82	0.67	0.77	0.66	0.61	0.63
- Lower	0.92	0.61	0.82	0.79	0.63	0.75	0.62	0.56	0.59
- Upper	0.94	0.70	0.86	0.84	0.71	0.80	0.70	0.66	0.68

2.4.2 Results

Overall, 62% of stores did not change names or locations between 2003 and 2004 in the MESA study sites. The average number of stores in census tracts also did not change significantly from 2003 to 2004, 4.5 ± 4.6 (mean (SD)) to 4.4 ± 4.5 (paired t test p value=0.19). ICCs for all three sites ranged from 0.61 to 0.84 for the eight types of stores as shown in Figure 2.2. 93.3% of the variation in the number of stores is between census tracts and only 6.7% is between years. Except for natural and organic food stores, agreement is similar across sites, racial/ethnic composition of tracts, and socioeconomic composition of tracts (not shown). Agreement for natural food stores between the years is lower in predominantly Hispanic tracts.

2.4.3 Discussion

Collection of dietary outcomes from the MESA study was concluded in January 2003. However, the earliest data available to characterize the exposure in this study, the local food environment, is from the following year 2003. Assuming that the same results can be inferred to the 2002-2003 period, results from this aim indicate that the food environment does not change significantly over a year providing valuable empirical evidence that a one year time lag between exposure and outcome may not significantly impact study results.

2.5 Conclusion

Results from these analyses indicate that not only are there less supermarkets in minority and poor areas echoing previous study results, but also, overall, there are fewer other types of stores in these neighborhoods. These results provide empirical support for the often-cited claim that food options differ across neighborhoods, and that healthy food options may be reduced in poor and minority areas. The location of food stores depends on a complex set of factors including marketing decisions of large corporations, the perception of the market by small businesses, consumer demand and purchasing power, competition, local regulations, and also local culture. Thus changing the local food environment will require intersectorial approaches. The data also shows that the patterns are complex. For example, poor and minority neighborhoods tend to have larger numbers of small stores, which may have substantial secondary benefits over small numbers of very large stores in terms of street life, social interactions, and traffic. Moreover, not all poor or minority neighborhoods have unhealthy food environments; in some instances poor, ethnic neighborhoods may offer more healthy choices than wealthier areas. Identifying the processes that allow poor and minority neighborhoods to attract and retain healthy food choices may suggest important avenues for intervention.

While various data sources for characterizing the food environment exist, sources that are feasible for research may be limited by the geographic level of the data available. In CBP for example, only information at the zip code level is available to protect the privacy of individual businesses. A commercial data source on the other hand may provide access to valuable information at a much smaller geographic level but may be a potentially unreliable data source for characterizing the food environment. Furthermore, existing data sources may not coincide exactly in time series with health indicators of potential research interest. Results from these analyses indicate that the commercial data source InfoUSA is a reliable source for characterizing the local food environment and that a time lag of one year between measures of the food environment and dietary data may not affect the validity of interpretations.

The infrastructure of the local food environment is yet another feature of the built environment that varies substantially across neighborhoods and may contribute to disparities and social inequalities in health. Accurate description of resources available to areas and area differences in the local food environment is an important first step. However, future research will need to move beyond descriptive studies to investigations of how best to effect change in the local food environment and studies of whether changes in the local food environment are associated with changes in residents' diets. Collaboration between community organizations, economic development planners, and public health researchers will be essential in moving this agenda forward.

2.6 References

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Chapter 3: Survey vs. GIS Based Characterizations of the Local Food Environment

Consuming the type of diet associated with lower chronic disease risk (1) has been linked to the local food environment in recent studies(2-10). In the context of the already high and escalating prevalence of obesity and its health consequences across the United States(11-13), determining how the food environment may promote the consumption of a healthy diet is crucial for the development of interventions. Although observational studies have linked the local food environment to diet(2-10), experimental studies remain rare (8-10;14)and the extent to which these associations reflect causal processes remains a topic of debate. One of the major challenges in studying the effect of the local food environment on diet is measurement of the local food environment. Most studies have used the presence of supermarkets as a proxy for the availability of healthy foods. However, these analyses ignore other types of smaller stores which may be present in neighborhoods such as fruit and vegetable markets, specialty food stores, meat and fish markets, etc. which may compensate for the absence of supermarkets. While empirical evidence suggests that smaller grocery stores carry fewer healthier items(15-18), having several different types of stores in a neighborhood may provide residents with a wider shopping base to meet dietary needs.

An alternative means of measuring the local food environment is to characterize the environment using survey responses of residents. This approach has been used to measure other area-level constructs such as access to recreational resources (19-23) but has not been used to date in the characterization of the local food environment. Survey based characterizations of the local food environment may tap into a different dimension of the food environment than more common locational based assessments of the environment which focus only on the presence of different types of stores. Survey based measures may capture what types of foods are actually available in the area and thus may reflect more than the simple presence of certain stores. On the other hand survey responses are affected by individual perceptions and respondents knowledge of the area, and therefore have their own sources of measurement error. Although GIS measures can be calculated for areas of different sizes, GIS measures require investigators to demarcate definite boundaries for areas based on convenience or a priori hypotheses. Survey based characterizations do not require the designation of potentially arbitrary boundaries for neighborhoods. Residents can either be asked to respond about an area of fixed size around their home or they can be asked to refer to the area they perceive as their neighborhood. Thus, areas in survey based measures can be based on individual perceptions of what constitutes a neighborhood. Residents can respond to questions regarding the area that is particularly relevant to them, although it has the disadvantage that different people may define their neighborhoods differently and therefore may be referring to areas of different sizes.

Documenting the interrelation between GIS and survey-based measures of measures of the local food environment is important for the validation of both types of measures and for the interpretation of studies that use them. No studies to date have investigated the relationship between survey based characterizations of the food environment and characterizations of the environment derived from locational GIS based measures. This study examined if the density of supermarkets within a mile of a person's home was related to the perceived availability of healthy foods (produce and low fat products). We also examined if the density of smaller stores or the number of different types of stores (diversity) is related to the perceived availability of healthy foods in the absence of supermarkets. Specifically, we hypothesized that greater density of supermarkets would be related to greater perceived availability of healthy foods. We also hypothesized that greater density of smaller stores, and greater variety of stores would be associated with greater perceived availability of healthy foods in the absence of supermarkets. The interaction between presence of supermarkets and presence of stores on reported availability of healthy foods was also explored in order to determine if both types of resources are synergistic, i.e. if living in an area with both types of stores is more beneficial in terms of reported availability of healthy foods than what would be expected from the separate additive effects of having both types of resources in the area.

3.1 Methods

Data was collected via a telephone survey of residents in 75 census tracts in Forsyth County, NC, 276 census tracts in parts of Baltimore City and Baltimore County MD, and 334 census tracts in Northern Manhattan and the Bronx NY as part of the MESA Neighborhood Study, an ancillary study to the Multiethnic Study of Atherosclerosis (MESA)(24) between January and August 2004. The main objective of the survey was to construct measures of neighborhood-level properties for these areas that could later be linked to clinical outcomes from the MESA study. Using random-digit-dialing, Clearwater Research, Inc. identified a sample of telephone numbers in the three geographic areas of interest. The GENESYS Sampling System (a list-assisted method developed and licensed by Marketing Systems Group) was used to establish the telephone number sampling frame for each study site. One adult 18 years of age or older was randomly selected to participate within each sampled household. Interviewers were trained and certified. The survey was administered in English or Spanish as necessary. We surveyed 5,988 respondents (1,752 in Maryland, 1,616 in North Carolina, and 2,620 in New York) residing within the geographic sampling frame. The final response rate was 46.5 percent. The sample was diverse in socioeconomic characteristics and race/ethnicity

Table 3.1: Neighborhoods and Cardiovascular Health Study Sample Size and Percent Distribution Demographics by Site

		MD	NC	NYC
	Sample Size	1746	1615	2627
Mean Age (SD)	5988	45.0 (17.6)	44.9 (17.3)	42.3 (16.5)
Gender				
Male	2111	34.6	37.3	34.4
Female	3877	65.4	62.7	65.6
Race/Ethnicity				
Asian	132	2.0	1.2	3.2
NH Black	1713	48.2	19.9	20.9
Hispanic	788	1.9	4.0	26.3
Other	211	4.5	1.3	4.3
NH White	3140	43.5	73.6	45.4
Household Income (missing=706)				
$0-11,999	792	11.8	9.7	20.4
$12-34,999	1429	31.1	27.8	23.9
$35-49,999	771	16.7	16.8	11.8
Over $50,000	2290	40.3	45.7	44.0

and was approximately representative of the areas from which it was drawn(25). Selected sample characteristics are described in Table 3.1

Three survey questions were used to measure self reported availability of healthy foods (SRA). Participants were asked to think of their neighborhood as the area within a 20 minute walk (or a mile) from their home and indicate the extent to which they agreed with the following statements: (1) a large selection of fruits and vegetables is available in my neighborhood, (2) the fresh fruits and vegetables in my neighborhood are of high quality, and (3) a large selection of low fat products is available in my neighborhood. All questions were coded on a five point Likert scale (0=strongly agree; 1=agree; 2=neither agree nor disagree; 3=disagree; 4=strongly disagree) and aggregated into a summary scale and used as a linear measure in analyses. The aggregate scale of reported availability was reverse coded so that a score of 0 indicated worst availability and 12 indicated best availability. Cronbach's alpha for the three items was high (α=0.78) (25). A sample of 120 individuals (40 at each site) was re-interviewed 2-3 weeks after the initial interview as part of a test-retest reliability study (final response rate = 80.0 percent). Test-retest reliability for the three items was also acceptably high (ρ=0.69 95% CI 0.57, 0.77) (25).

The availability of different types of stores in a neighborhood was measured by the densities of stores per unit area within a mile of a person's residence. Densities were estimated by the kernel density method(26;27) using ArcGIS v.9.1 (ESRI, Inc., Redlands, CA). This method allows for the estimation of densities of stores for areas of different sizes smoothed over space. Densities were estimated based on point locations of food stores with each represented on a map by a smoothed cone (kernel) centered at that location. The radius of the cone, or bandwidth, represents the window size, 1 mile in this study. For a 1 mile radius, cones for different food stores overlap when stores are less than two miles apart. The three study areas were partitioned into 10 meter grid cells and the density value of each cell was assigned by summing the densities corresponding to each of the overlapping cones. The density for a person located in a particular cell represents the density of stores per square mile within a mile of that person's home. Densities were weighted according to a Gaussian distribution so that resources more proximate to respondents' residents are weighted more heavily and thus more importantly than those farther away (27). Population density adjusted densities were estimated by dividing the store densities by the corresponding population densities created from census block group data using similar methods(27). These densities can be interpreted as food stores per 100,000 population within one mile of a respondent's residence.

Two types of densities were investigated, supermarkets per square mile and all other smaller stores (all non supermarkets including grocers, convenience stores, fruit and vegetable markets, specialty stores, natural food stores, meat and fish markets, and bakeries) per square mile, with information obtained from the proprietary information service, InfoUSA, in November of 2003. Businesses were classified into the following categories using supplemented Standard Industrial Classification codes created by InfoUSA: grocers and supermarkets (541101, 541104-541106); convenience stores (541102, 541103); meat and fish markets (5421, 549907, 549911); fruit and vegetable markets (543101, 543102, 543103, 549933); bakeries (5461); natural food stores (549901, 549909, 549935); specialty food stores (SIC 549910, 549912, 549914, 549916-549921, 559923, 549926-549928, 549930, 549937). Manufacturing plants and corporate headquarters as identified by the InfoUSA database were excluded from analysis due to potential inaccessibility to the public. Following prior work(28;29), supermarkets were differentiated from grocers based on chain name recognition and/ or an annual payroll of greater than 50 employees. The main area investigated was 1 mile to correspond with survey questions which specifically requested participants to report on resources within 1 mile around their residence. Heterogeneity in the food environment was represented by a variable, diversity, which was calculated by summing the number of different types of food stores (range 0 to 7) in areas without supermarkets. The sensitivity of results to varying definitions of neighborhoods was tested using 2 and 5 mile window sizes for densities.

In order to investigate the associations between reported healthy food availability and the density of stores, the food availability scale for each survey participant was modeled as a function of the densities of supermarkets, the densities of smaller stores in the absence of supermarkets, and the number of different types of stores in areas without supermarkets in three separate models using linear regression in SAS version 9.1. Densities of smaller stores and the number of different types of stores in areas without supermarkets were included in separate models due to the high correlation between these two variables (Pearson correlation = 0.73). The food availability scale was logged for ease of interpretation in analyses so that coefficients can be interpreted as relative differences (or percent differences) in availability. Interactions between small stores and supermarkets were investigated by fitting separate models with supermarket densities, small store densities, and their interaction to the full data. All models were adjusted for site and selected personal characteristics including race and income. These variables were considered potential confounders because densities may be patterned by race, income and site (30) and all three variables could be related to food availability reports independently of their association with density. Site was also examined as a potential effect modifier. In order to make effect size units comparable between the different types of stores in analyses, density measures were pooled across sites and divided into three categories. Areas with less than 0.5 stores per square mile or 0.5 stores per 100,000 population were classified as having poor access to stores, those with less than the average number of stores were classified as having moderate access, and those with more than the average number of stores were categorized as having the best access. Diversity in the food environment was categorized in a similar manner. Areas with only 1 type of store were classified as having poor access to a diverse food environment, those with less than 4.8 (the average) different types of stores were classified as having moderate access to a diverse food environment, and those with more than the average number of different types of stores were categorized as having the best access. Main models were run for 1 mile densities but 2 mile and 5 mile densities were examined in sensitivity analyses. Densities were examined both per area and population adjusted.

3.2 Results

Of the 5988 survey respondents 96.4% (n=5774) responded to all three food availability questions and were included in these analyses. Descriptive statistics are shown in Table 3.2. The mean healthy food availability score was 7.4 with a standard deviation (SD) of 3.1. Reported healthy food availability differed by site with New York residents reporting higher availability of healthier foods within one mile of their home than residents in Maryland and North Carolina (7.9 for New York vs. 7.0 for Maryland

Table 3.2: Mean Reported Availability of Healthy Foods (SRA) and Densities of Stores within 1 Mile of Residence by Site and Selected Personal Characteristics

		Stores per square mile		Stores per 100,000 people		
	SRA Score	Supermarkets	Other Stores	Supermarkets	Other Stores	Number of Types of Store
Overall	7.4	2.0	29.8	2.3	21.7	4.8
Food Environment Measures[1]						
Poor Access	-	0.1	0.1	0.1	0.02	1.0
Moderate Access	-	1.2	6.6	1.3	12.7	3.2
Best Access	-	4.9	63.9	6.1	33.8	6.5
Site[2]						
MD	7.0	0.6	8.6	2.2	20.6	4.0
NC	6.8	0.3	1.4	3.5	19.5	2.0
NY	7.9	4.1	61.4	1.5	23.8	7.0
Race/Ethnicity[2]						
Asian	8.1	3.0	38.5	2.9	22.2	7.0
NH Black	6.5	1.3	26.5	1.7	23.8	5.0
Hispanic	7.1	2.5	60.7	1.5	27.8	7.0
Other	7.1	2.2	35.1	1.9	23.1	6.0
White	7.9	2.3	23.1	2.7	18.9	4.0
Household Income[3]						
$0-11,999	7.6	2.1	29.9	2.6	21.2	6.0
$12-34,999	6.7	1.9	44.1	1.7	28.4	5.0
$35-49,999	7.0	1.6	29.3	2.3	23.9	5.0
Over $50,000	7.9	2.5	26.9	2.3	18.3	5.5

[1]Distributions of each type of store was pooled across sites to create tertiles [2] P-values for differences between means using ANOVA < 0.01 [3] P-value for trend < 0.01

and 6.8 for North Carolina p-value<.0001).

New York residents also had significantly more supermarkets and smaller stores per area as well as a greater number of different types of stores within a mile than residents of the other two sites most likely due to the higher population density of this area (65,230 people per square mile for New York vs. 747 and 4127 people per square mile for North Carolina and Maryland respectively). Population adjusted densities of supermarkets and other smaller stores were more comparable across sites with North Carolina and Maryland residents having more supermarkets per 100,000 population than New York. MD and NC residents appeared to have a more homogeneous food environment in terms of the number of different types of stores within a mile of their home. Minorities (except for Asians) reported lower availability of healthy foods than whites and lived in areas with fewer supermarkets per population. In contrast, minorities lived in areas with greater densities of smaller stores and with more different types of stores. Patterns in reported food availability and supermarket densities by income were not as consistent due to strong site confounding. 59.5% of those earning under $12,000 annually reside in New York where people rate their environments better and there are more stores per square mile than the other two sites.

Table 3.3 shows percent differences in the healthy food availability score across categories of unadjusted store densities. Estimates are shown after adjustment for site, gender, race/ethnicity, and income. Associations between reported availability and access to stores using population adjusted densities were generally similar to the unadjusted results except where noted. Respondents with annual household incomes over $50,000 consistently reported better availability than other income groups. Blacks reported the worst availability of healthy foods in their neighborhood regardless of what types of stores were present. Findings for other race/ethnic groups were not as consistent across all the models.

Respondents who lived in areas with poor access to supermarkets rated the selection and quality of produce and low fat foods 16% lower than those who lived in areas with the highest densities of supermarkets (95% CL -19.4,-13.2). Respondents who had moderate access to supermarkets (the intermediate category of densities) also rated the availability of healthy foods significantly lower than those with the best access to supermarkets around their home (7.1% lower 95% CI –9.8, -4.3). In areas without supermarkets, neither densities of smaller stores nor diversity in the food environment was associated with the selection and quality of healthy foods in unadjusted analyses. Because of the highly left skewed distribution of densities of smaller stores those classified as having the best access to stores only comprised 2% of the population. Models were repeated using tertiles to categorize other stores per square mile and those who had poor access to smaller stores ranked the availability of health foods 5% worse than those with the best access (4.5% lower 95% CL -8.8, 0.1). In population adjusted analyses, having poor access to smaller stores was significantly associated with the selection and quality of healthy foods (4.8 worse for poor access (22.4% of population) vs. best access (24.4% of population) 95% CI -9.5, 0.2). Interactions between densities of supermarkets and smaller stores in areas were negative (-0.1 95% CI -0.1, 0.0 (data not shown)) so that there was some evidence that the effect of having both types of stores in a

Table 3.3: Adjusted Percent Changes in Reported Availability of Healthy Foods and 95% CL for Poor and Moderate Access to Stores vs. Best Access to Stores[1]

Availability of Stores	**Supermarkets**[2] (n=5774)	**Other Stores**[3] (n=2044)	**Diversity**[4] (n=2044)
Poor vs. Best Access	-16.4 (-19.4,-13.2)	-2.6 (-16.8,14.1)	-1.2 (-6.3,4.2)
Moderate vs. Best Access	-7.1 (-9.8,-4.3)	3.8 (-11.0,21.0)	5.2 (0.2,10.4)
Site			
MD	1.7 (-1.6,5.2)	-2.2 (-17.7,16.2)	-3.0 (-15.6,11.6)
NC	-1.4 (-4.9,2.3)	-6.7 (-21.6,11.0)	-7.6 (-19.7,6.2)
NY	Referent	Referent	Referent
Race/Ethnicity			
Asian	-0.7 (-6.5,5.4)	2.7 (-12.9,21.1)	2.7 (-12.8,21.1)
NH Black	-12.9 (-14.8,-11.0)	-9.1 (-12.6,-5.4)	-8.7 (-12.3,-4.9)
Hispanic	-10.1 (-12.8,-7.3)	5.8 (-3.9,16.5)	6.1 (-3.6,16.8)
Other	-10.9 (-15.2,-6.4)	-6.3 (-15.8,4.2)	-6.5 (-15.9,4.1)
NH White	Referent	Referent	Referent
Household Income			
$0-11,999	-6.8 (-9.6,-4.0)	-10.1 (-15.8,-3.9)	-9.3 (-15.0,-3.1)
$12-34,999	-3.5 (-5.8,-1.2)	-2.6 (-6.7,1.8)	-1.8 (-6.0,2.6)
$35-49,999	-6.5 (-9.2,-3.8)	-8.5 (-13,-3.7)	-8.2 (-12.8,-3.4)
over $50,000	Referent	Referent	Referent

[1] Adjusted for site, gender, race, and income. Based on densities of stores per square mile pooled across sites

[2]Poor access < 0.5 (35.4%), Moderate = 0.5-2.0 (30.8%), Best > 2.0 (33.8%)

[3]Poor access < 0.5 (41.2%), Moderate = 0.5-29.8 (56.7%), Best > 29.8 (2.1%)

[4]Poor access = 1 (39.0%), Moderate = 0.5-4.8 (43.4%), Best > 4.8 (17.6%)

neighborhood is not additive i.e. having both supermarkets and smaller stores is not more beneficial than having either of these features of the food environment alone.

Reported availability of healthy foods was positively associated with the densities of supermarkets in the neighborhood across sites as shown in Table 3.4, however, effect sizes were greater in North Carolina and Maryland than in New York. North Carolina and Maryland respondents who had poor access to supermarkets near their home rated the quality and selection of healthy foods18-19% lower than those with the best access to supermarkets while those in NY rated their food environment only 7% lower (p-value for heterogeneity between sites <0.0001). In population adjusted analyses, regional variation still existed but New York was more comparable to the other two sites (-16.6 95% CI -22,-10.9 for New York vs. -13.0 and -19.3 for MD and NC, respectively, p-value for heterogeneity between sites <0.0001). Only NC respondents who had poor access to smaller stores located within a mile of their home rated the quality and selection of produce and low fat products significantly lower than those who lived in areas with the best access to smaller stores when no supermarkets were present, (8.1% lower 95% CL -12.2, -3.7, p-value for heterogeneity between sites = 0.0009). Relative differences in reported availability for limited access to other stores and a diverse food environment are not shown for NY because no respondents were categorized as having poor access to either of these food environments. The relationship of reported availability with living in a more heterogeneous food environment varied by site but was consistently statistically insignificant.

Table 3.5 shows percent changes in reported availability for the bottom category (poor access) compared to the top density category (best access) for densities of 1, 2, and

Table 3.4: Site Specific Adjusted[1] Percent Changes in Reported Availability of Healthy Foods and 95% CL for Poor Access to Stores vs. Best Access to Stores

Availability of Stores	Supermarkets	Other Stores	Diversity
Maryland			
Poor vs. Best Access	-18.2 (-28.3,-6.8)	-7.9 (-23.3,10.7)	5.0 (-3.1,13.8)
North Carolina			
Poor vs. Best Access	-19.1 (-31.9,-4.1)	-8.0 (-12.1,-3.6)	-6.4 (-13.3, 1.2)
New York			
Poor vs. Best Access	-7.0 (-16.3,3.3)	-	-

[1]Models adjusted for respondent race and income

5 miles around participants' homes adjusted for site, race/ethnicity, and income. Respondents with the poorest access to supermarkets rated the availability of healthy foods 16.4% lower than those with the best access to supermarkets in population unadjusted analyses. This effect decreased significantly as the window for which the density was calculated increased: 7% lower (95% CI -11.5, -2.6) for the bottom vs. the top category of 2 mile densities and no association for the 5-mile densities. Population adjusted results were less consistent. Effects did not differ between 1 and 2 mile windows and were statistically insignificant at 5 miles. Associations of densities of other stores or diversity with reported availability among persons residing in areas with no supermarkets did not differ across window sizes (not shown).

3.3 Discussion

This study found that on average respondents who lived in areas with poor access to supermarkets rated the selection and quality of produce and low fat foods 16% lower than those who had the best access to supermarkets near their home. The relationship between supermarket density and reported availability of healthy foods was greatest in North Carolina and weaker in Maryland and New York. Having poor access to smaller stores in the neighborhood when supermarkets were not present was significantly associated with worse selection and quality of healthy foods as hypothesized in only North Carolina. Living in a local food environment that was more heterogeneous was not associated with better reported availability. Having both supermarkets and small stores was not significantly more beneficial than having either of these features of the food environment alone. The effect of supermarket density on reported availability decreased as the size of the area for which density was calculated increased in unadjusted analyses.

Population adjusted results were generally similar in magnitude, direction, and significance to unadjusted resulted so that how many people a store services may not be as relevant as just having a store present in the neighborhood. Significant residual

Table 3.5: Adjusted Percent Change in Reported Availability and 95% CL for Poor Access vs. Best Access to Supermarkets within 1, 2, and 5 Miles of Residence

Model	1 mile	2 mile	5 mile
Unadjusted	-16.4 (-19.4,-13.3)	-7.2 (-11.5,-2.6)	5.6 (-1.1,12.8)
Population Adjusted	-16.7 (-18.8, -14.6)	-19.7 (-22.6,-16.6)	-14.7 (-36.8, 15.3)

Models adjusted for race, income, and site individual level differences existed independently of the types of stores present in neighborhoods. These differences may be accounted for by the fact that the quality of the stores represented in these analyses was not surveyed in these analyses. Stores that may be classified in the same category may offer vastly different healthy options depending on the sociodemographic features of the neighborhood (31).

There was some evidence that there were differences by site in the relationship between reported availability of healthy items and the location of stores. For unadjusted densities, associations were weak in New York and stronger in NC and MD. In the context of the very high population density of New York, spatial availability may be less important. Interestingly these site differences were not present in population-adjusted analyses. Because of the very large site differences in population density, in NY no respondents were categorized as having poor access to other stores or to a diverse food environment both in unadjusted and population adjusted analyses. Therefore reported results for relative differences in the availability of healthy foods for limited access to these types of food environments represent only two of the three sites.

There were no clear associations of reported availability of healthy items with smaller grocery stores or diversity in the local food environment suggesting that only having supermarkets present in the neighborhood, not smaller stores, translates into better availability of healthy items even when there are several different types of smaller stores available. Our results are consistent with previous studies that have shown that areas served by supermarkets have better availability of healthier food items. Sloane et al inventoried selected markets in the Los Angeles metropolitan area and found that important food items for living a healthier life such as low-fat dairy, whole grain products, and lean meats were significantly less available and of lower quality and less variety in areas of high African American concentration (6) most likely due to the documented lack of supermarkets in predominantly minority areas(30;32;33). A survey of stores in New York also reported that only 1 in 3 smaller neighborhood stores sell reduced fat milk compared to 9 in 10 supermarkets and less than a third carry fresh produce compared to 91% of supermarkets (15). Similarly, mean quality of fresh produce was significantly lower in the predominately African-American, low-SEP community than in the racially heterogeneous, middle-SEP community where supermarkets are less likely to be located(18;33). In a recent study by Jetter et al in neighborhoods served by smaller grocery stores, access to whole-grain products, low-fat cheeses, and lean ground meat was limited with 64% of all items unavailable in small grocery stores(16).

The GIS measures used in this study have several important limitations. These measures were derived from a commercial database established for marketing purposes rather than data collected for research purposes. Primary data collection across the very broad areas that we studied was not feasible. Although there is likely some under-representation of stores it is unlikely that these patterns differ systematically across neighborhoods. The use of this commercial database allowed us to systematically examine three large diverse areas and multiple types of food stores, key strengths of our analyses. The GIS measures used also relied on supplemented SIC codes to classify businesses into store types. Some misclassification is probable; however, it is also unlikely that misclassification differed significantly across neighborhoods. We distinguished supermarkets from other grocers based on prior work(28;29). In sensitivity analyses we compared our supermarket classification scheme to other methods (34-36) and found that only 8% of businesses were classified differently. Thus our results are likely to be robust to different approaches to classifying supermarkets. Although any store classification scheme has its limitations, the use of a standard system allows replication across studies.

Survey based characterizations may be also subject to certain limitations. Respondents were asked to refer to the area one mile around their home when answering questions about resources available in their neighborhood however respondents may misestimate the geographic bounds of one mile which may introduce misclassification. Survey measures may also be limited by the fact that how respondents view and rate their local food environment may be either positively or negatively influenced by various individual experiences and personal behaviors. For example, people who reside and shop mostly in neighborhoods which consistently offer fewer healthier options may rate the quality and availability of low fat foods and produce better than residents living in the same area who may be more aware of deficiencies in their neighborhood because they shop outside of their neighborhoods.

Overall our results indicate that characterizations of the local food environment based on survey responses are associated with GIS based characterizations of the food environment. However, reported availability is obviously not synonymous with densities of stores determined through existing locational data sources. Using survey based characterizations of the local food environment may allow us to tap into a different construct than simply recording the presence or absence of stores in an area and may potentially lead to different conclusions when relating these measures to dietary outcomes. Having more supermarkets in an area has been associated with healthier diet in several studies however using a survey based characterization of the food environment may produce different conclusions. Survey based measures may capture what types of foods are actually available to residents unlike the locational measures that have frequently been used in the literature and may therefore perhaps be more strongly associated with diet. Similar literature on physical activity and self reported compared to objective characterizations of the environment have resulted in mixed conclusions depending on which measure is used (21;37;38). Future research on determining how the local food environment is related to diet should also explore survey based measures when characterizing the food environment.

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Chapter 4: Associations of the local food environment with diet quality: a comparison of GIS and survey assessments

Factors related to access to healthy foods have received increasing attention (1-6) due to the rapidly increasing and disproportionate amount of obesity among Americans (7). Although causal pathways have yet to be established, local food environments and residents' diets have been linked in observational studies (4;8-10) and in preliminary data from natural experiments (11). In the US, certain minority groups and the poor may be particularly disadvantaged in terms of access to healthy foods due to the differential placement of supermarkets outside of their communities (3;12-23). The location of supermarkets and other food stores may limit the ability of minorities and the poor to meet recommendations for a healthy diet and consequently may contribute to health disparities in related chronic diseases including heart disease, obesity, and diabetes.

Establishing whether features of the local food environment are causally related to resident's dietary behaviors would have important policy implications. Efforts to prevent chronic disease such as obesity and diabetes may need to include strategies aimed at improving access to healthy foods in neighborhoods (24-30). However, the current literature on the impact of the local food environment on diet is limited in that analyses are based mainly on administrative areas which may not correspond to areas relevant to food purchasing behavior. Furthermore no studies to date have incorporated other types of measures of the of the local food environment including survey measures which may provide information on the foods actually available to residents which is not captured by data on the location of food stores. However, characterizing the local food environment based solely on the perception of a study participant in whom diet is also assessed could potentially result in spurious associations (sometimes referred to as same-source bias). Depictions of the local food environment based on a single report may also be unreliable. Recent work has highlighted the utility of measuring features of residential environments through the aggregation of survey responses of multiple area residents using ecometric techniques(31;32). This approach has not been used to date in the study of local food environments and diet.

All but one previous study measuring the impact of the local food environment on diet (4;9-11) focused on individual dietary components (e.g. fruit and vegetable intake, fat intake etc.) which may not adequately represent the overall quality of the diet. Because foods are not consumed in isolation and because of the potential for synergy between foods (33), measuring diet quality using empirically derived dietary patterns and a priori indices may provide insights into the relationship of the local food environment and dietary behaviors which are not captured by investigations of single components.

Using data from three large and diverse geographic areas, we investigated the relationship between the local food environment and diet using three alternate and complementary measures of the local food environment (1) GIS-derived data on the location of supermarkets (2) self reported characteristics of the local food environment and (3) a measure of the quality of the local food environment derived by aggregating survey responses of residents of the same neighborhoods as study participants. Diet quality was examined using empirically derived dietary patterns, a priori indices, and more traditional dietary measures.

4.1 Methods

The Multi-Ethnic Study of Atherosclerosis (MESA) is a longitudinal study of cardiovascular disease conducted at six study sites(34). The MESA Neighborhood Study, an ancillary study to MESA on which these analyses are based, collected additional information on neighborhood characteristics for participants residing at three of the six sites: Forsyth County NC, Baltimore City and County, MD, and New York City New York. At each of the three sites, MESA sampled approximately 1000 participants through a variety of population-based approaches. Only persons free of clinical cardiovascular disease were eligible. White and non-Hispanic black participants were recruited at all three sites. Hispanic participants were recruited only at the New York site. Analyses are based on MESA baseline visit data collected between July 2000 and September 2002. The study was approved by Institutional Review Boards at each site and all subjects gave written informed consent.

4.1.1 Dietary Outcomes

Usual food and nutrient intakes of MESA participants were assessed through a staff-assisted, self-administered 120 item food frequency questionnaire (FFQ) and dietary supplement form. The questionnaire was developed according to a validated format by Block et al. (35) and adapted from the Insulin Resistance Atherosclerosis Study instrument which has comparable validity for non-Hispanic White, African American, and Hispanic persons (34). The questionnaire was modified to include foods typically eaten in Chinese populations and to collect supplemental information about whole grains, processing of plant food, and flavonoids. Participants recorded the serving size (small, medium, or large) and frequency of consumption (average times per day, week, or month) of specific beverages and foods. Nine frequency options were given that ranged from "rare or never" to a maximum of '≥ 2 times/d' for foods and a maximum of '≥ 6 times/d' for beverages. Forms were cleaned and processed centrally at the MESA Diet Assessment Center at the University of South Carolina. The DietSys Nutrient Analysis program was used to calculate average daily intake of nutrients. Forms that were not completed by participants and forms that were considered unreliable or incomplete for processing were not analyzed. Questionnaires with implausible responses were also excluded including those with too few (<5 for men or <4 for women) or too many (>30) foods reported per day, questionable high frequency of foods skipped (≥ 18 foods), too many foods coded with the same frequency (≥ 90 foods), or coded as the same serving size (≥ 119 foods), and those reporting extreme energy intakes, >6000 or <600 kcal/d. A total of 12.7% of forms were missing, unreliable, or incomplete and subsequently excluded.

Four dietary outcome variables were derived from the MESA dietary questionnaire: the alternate healthy eating index, an empirically derived dietary pattern, the proportion of the diet from fat, and the number of fruit and vegetable servings per day.

The Alternate Healthy Eating Index (AHEI) is a summary index of dietary patterns and eating behaviors that have been consistently associated with lower risk for chronic disease in clinical and epidemiologic investigations (36). The AHEI was twice as strong at predicting major chronic disease and cardiovascular disease risk (37-39) as the original Healthy Eating Index (40;41) developed by the US Department of Agriculture Center for Nutrition Policy and Promotion to measure conformity to the Dietary Guidelines for Americans (42).

The AHEI consists of 9 components. It incorporates certain aspects of the original Healthy Eating Index (e.g., fruit and vegetable intakes) but also quantifies additional qualitative recommendations by Dietary Guidelines (e.g., choosing more fish, poultry, and whole grains, and drinking in moderation) and was derived following guidelines from prior work except where noted (36). Components 1-3 measure servings per day of 1) vegetables, 2) fruits, and 3) nuts and soy protein. Component 4 measures the ratio of white to red meat. Component 5 measures the total grams of cereal fiber consumed daily. Previous work used fiber from all grain sources (36) which was not available in this study. Component 6 measures *trans* Fat intake as a percentage of daily energy intake. Components 7 and 8 measure the ratio of polyunsaturated to saturated fatty acids and the servings of alcohol per day. These 8 components are scored from 1-10, with 10 indicating that the dietary recommendation is fully met. Component 9 measures the use of multivitamins once per month as a dichotomous variable and is scored as either 2.5 points for nonuse or 7.5 points for use. Multivitamin use was defined as use for over 5 years in previous work (36), however long term usage information was not available in this study. All component scores were summed to obtain a total AHEI score ranging from 2.5 (worst) to 87.5 (best).

An empirically derived dietary pattern developed by Nettleton et al (43) using a principal components analysis of MESA FFQ data was also investigated as a measure of overall diet quality. The dietary pattern hereafter referred to as a 'western' diet was characterized by greater consumption of fats and processed meats and was associated with elevated levels of biochemical markers of inflammation and endothelial activation, precursors to atherosclerosis in MESA (43). Details on the development of the pattern are provided elsewhere (43). Higher scores indicate higher intake of fats and oils, high-fat and processed meats, fried potatoes, salty snacks, and desserts.

Previous work on the local food environement suggests that limited access to low fat products and produce in areas not served by supermarkets(5;15-17;19) may affect dietary choices like fruit and vegetable intake and fat consumption. Therefore, daily proportion of calories from fat and daily food guide pyramid servings of fruits and vegetables were also investigated as outcomes.

4.1.2 Local Food Environment Measures

Three different measures of the local food environment were investigated (1) GIS-derived data on the location of supermarkets (2) characteristics of the local food environment reported by MESA participants and (3) a measure of the local food environment derived by aggregating responses of other residents of MESA neighborhoods (henceforward referred to as the ecometric measure). Food environment measures were investigated in parallel but separate analyses and contrasted.

GIS Based Characterizations of the Local Food Environment

Information on supermarkets was obtained from InfoUSA in November of 2003. Supermarkets and grocers were identified using supplemented Standard Industrial Classification codes 541101 and 541104-541106. Following prior work(12;13), supermarkets were differentiated from grocers based on chain name recognition and/ or an annual payroll of greater than 50 employees. Manufacturing plants and corporate headquarters as identified by the InfoUSA database were excluded from analysis due to potential inaccessibility to the public.

Densities of supermarkets per square mile within a mile of a person’s residence were estimated by the kernel density method(44;45) using the Spatial Analyst extension of ArcGIS v.9.0 (ESRI, Inc., Redlands, CA). This method allows for the estimation of densities of stores for areas of different sizes smoothed over space. The main area investigated was 1 mile to correspond with survey questions which specifically requested participants to report on resources within 1 mile around their residence. Densities were weighted according to a Gaussian distribution so that resources more proximate to respondents’ residence were weighted more heavily than those father away (45). Population density adjusted densities were estimated by dividing the store densities by the corresponding population densities created from census block group data using similar methods(45). These densities can be interpreted as supermarkets per 100,000 population within one mile of a respondent’s residence.

MESA Survey Based Characterizations of the Local Food Environment

Three survey questions administered to MESA participants were used to measure accessibility of shopping and availability of food products. Participants were asked to think of their neighborhood as the area within about a 20 minute walk (or about a mile) from their home and indicate the extent to which they agreed with the following statements: (1) lack of access to adequate food shopping is a problem in my neighborhood, (2) a large selection of fruits and vegetables is available in my neighborhood, and (3) a large selection of low fat products is available in my neighborhood. Responses to question 1 was coded on a four point Likert scale (1-very serious problem 2-somewhat serious problem 3-minor problem 4-not really a problem) and responses to items 2 and 3 were coded on a five point Likert scale (0=strongly agree; 1=agree; 2=neither agree nor disagree; 3=disagree; 4=strongly disagree). Responses were coded so that higher scores indicate better perceived accessibility of shopping and low fat products and produce and were aggregated into a summary scale (Cronbach's coefficient alpha=0.70).

Ecometric Characterization of the Local Food Environment

An ecometric measure of the local food environment was derived from data collected via a telephone survey of residents in the three study sites,(34) between January and August 2004. The main objective of the survey was to construct measures of neighborhood-level properties for these areas that could later be linked to MESA participants. Using random-digit-dialing, we identified a sample of telephone numbers in the three geographic areas of interest. One adult 18 years of age or older was randomly selected to participate within each sampled household. Trained and certified interviewers administered the survey in English or Spanish as necessary. 5,988 respondents residing within the geographic sampling frame were surveyed (1,752 in Maryland, 1,616 in North Carolina, and 2,620 in New York). The final response rate was 46.5 percent. The sample was diverse in socioeconomic characteristics and race/ethnicity and was approximately representative of the areas from which it was drawn (32).

Responses to three questions pertaining to the (1) quality and (2) availability of fresh fruits and vegetables and (3) the availability of low fat products in the neighborhoods were used to measure reported availability of healthy foods. In responding to the questionnaire, participants were asked to refer to the area one mile from their home. All questions were coded on a five point Likert scale (0=strongly agree; 1=agree; 2=neither agree nor disagree; 3=disagree; 4=strongly disagree) and aggregated into a summary scale. Analyses using this measure used census tracts as proxies for the local area. Responses from survey respondents residing within each census tract were reverse coded so that a score of 0 indicated worst availability and 12 indicated best availability. Conditional empirical Bayes estimates were created using three level hierarchical linear models to obtain an aggregate measure of the availability of healthy foods for each census tract. Conditional empirical Bayes estimates were used rather than crude means (average aggregate responses of individuals within each tract) because half of all tracts in the study area had less than eight people to report on the environment (range 1-64) which is considered insufficient to generate reliable estimates (31). Conditional empirical bayes estimates improve upon the crude mean by pulling those neighborhoods that are unreliable (i.e few people within neighborhood, or not enough agreement regarding construct amongst between neighbors) towards the mean of neighborhoods with a similar characteristics known to be predictive of food availability (in our case a series of census measures) (32). Both internal consistency and test-retest reliability of the scale were high (Cronbach's alpha = 0.78; test-retest reliability: = 0.69 95% CI 0.57, 0.77) (32).

4.1.3 Statistical Analyses

Of the 3265 MESA participants at baseline residing in the three study sites, 2963 agreed to participate in the MESA Neighborhood Ancillary Study. An additional 92 participants were excluded due to missing geocoded addresses. 388 participants were excluded because information was not available on 1 or more dietary indicators and an additional 97 individuals were excluded because of missing food environment measures. The final analytic sample size was 2386 participants who had complete data on dietary outcomes and food environment measures.

The distribution of the four dietary outcomes and the three measures of the local food environment were examined by site, sex, race/ethnicity, and income. Agreement between measures of the local food environment (in categories based on quartiles) was assessed using weighted kappa statistics (46). Binomial regression (47) was used to model the probability of meeting dietary recommendations or having a healthy diet as a function of measures of the local food environment. All outcome measures were dichotomized. MESA participants whose AHEI score ranked in the top quintile (score above 54) were classified as having a good diet. Recent studies have found that being in the top quintile was associated with a 11-20% reduced risk of overall chronic disease and 28-39% reduced risk of cardiovascular disease compared to being in the bottom quintile (39). MESA participants scoring in the bottom quintile of the western diet (those consuming less fats, processed meats, salty foods, and desserts) were classified as having a healthy diet. Recent analyses in this cohort have shown that being in the lowest quintile is associated with lower levels of markers of inflammation and endothelial activation (43). Participants who consumed a minimum of five servings daily of fruits and vegetables and a maximum of 30% of daily energy intake from fat were considered to meet the dietary recommendations of the Dietary Guidelines for Americans (42). To make results comparable across indicators, the local food environment measures were categorized into quartiles based on the full distribution. Associations were adjusted for personal characteristics including age, gender, race/ethnicity, and per capita household income. Race/ethnicity was self-reported and classified as Hispanic, non-Hispanic white, and non-Hispanic black. Participants selected their total combined family income for the past 12 months from 13 income categories; continuous family per capita income was calculated by dividing the interval midpoint of family income (dollars) by the number of persons supported. In sensitivity analyses we also investigated the robustness of results to additional adjustment for education classified into 9 categories.

4.2 Results

Selected sociodemographic characteristics of the study sample are shown in Table 4.1. Participants ranged in age from 45 to 84 with an average age of 63. Slightly over half of the population was female, 15% were Hispanic, and 44% were Non Hispanic black. Respondents from the New York site were more likely to have a less westernized diet and meet dietary fat recommendations than those residing in Maryland or North Carolina sites (Table 4.2). Women were more likely to meet fruit and vegetable recommendations and

Table 4.1: Multi-Ethnic Study of Atherosclerosis Selected Sample Demographics and Distribution by Site

		MD	NC	NYC
Sample Size	2384	785	839	760
Mean Age (SD)	62.6 (9.9)	63.3 (9.9)	62.5 (9.7)	62.0 (10.3)
Gender				
Male	1093	47.5	46.9	43.8
Female	1293	52.5	53.1	56.2
Race/Ethnicity				
NH Black	995	49.0	42.4	33.4
Hispanic	351	0.0	0.2	45.9
NH White	1038	51.0	57.3	20.7
Per Capita Income (missing=108)				
$0-14,999	587	22.1	16.8	38.6
$15-24,999	678	29.8	30.8	28.8
$25-34,999	517	24.1	27.3	16.6
Over $34,000	496	24.0	25.1	16.0

follow a good diet as defined by the western dietary pattern than men. Whites were more likely to have a healthy diet than blacks and Hispanics when evaluating the diet using AHEI but were less likely than the other groups to meet recommendations for dietary fat. Hispanics were more likely than whites or blacks to have a good diet based on the Western dietary pattern measure. Income was positively associated with the probability of having a good diet based on AHEI scores but the opposite pattern was observed for the western diet measure. The percentages of people meeting dietary recommendations for fruit and vegetable intake and fat were similar across income levels.

The three different measures of the local food environment were positively related although not highly correlated. Agreement between quartiles of densities of supermarkets within 1 mile of participants' homes with quartiles of survey measures and ecometric survey measures were low (weighted kappa = 0.34 and 0.11, spearman correlation = 0.49 and 0.15 respectively, data not shown). Agreement between quartiles of survey measures and ecometric survey measures was also low (weighted kappa = 0.16, spearman correlation = 0.24). Ninety-five percent of participants stated that they used supermarkets for most of the household food shopping, and 47% of participants stated that they did most of their food shopping within 1 mile of the home, and 41% of respondents indicated that they did most of their food shopping within 1-5 miles of their homes (not shown).

Overall, 41% of participants did not have a supermarket located within one mile

Table 4.2: Proportion of Participants Meeting Dietary Recommendations and Mean (SD) Measures of the Local Food Environment by Site and Selected Personal Characteristics

	% Meeting Dietary Recommendations				Local Food Environment Measures			
	AHEI[1]	Western Dietary Pattern[2]	Dietary Fat[3]	Fruit and Vegetables[4]	Supermarket per sq mi	Supermarket per population[5]	Survey	Ecometric Survey
Overall	20.0	20.0	39.7	38.4	1.4 (1.9)	1.9 (3.1)	7.3 (2.5)	10.0 (1.6)
Site								
MD	20.9	14.5	40.2	38.7	0.5 (0.6)	1.9 (2.8)	7.1 (2.5)	10.0 (1.6)
NC	17.5	12.2	31.3	37.8	0.2 (0.4)	2.2 (4.6)	6.1 (2.5)	9.6 (1.3)
NY	21.7	33.9	47.4	38.7	3.4 (2.0)	1.4 (0.7)	8.7 (1.7)	10.2 (1.9)
P-value[3]	0.0655	<.0001	<.0001	0.9136	<.0001	<.0001	<.0001	<.0001
Gender								
Male	19.0	15.3	38.3	34.5	1.4 (1.9)	1.9 (3.3)	7.3 (2.6)	9.9 (1.6)
Female	20.9	24.0	40.9	41.7	1.3 (1.9)	1.8 (3.0)	7.3 (2.5)	10 (1.6)
P-value	0.2189	<.0001	0.1426	0.0002	0.0914	0.3367	0.6331	0.4129
Race/Ethnicity								
NH Black	19.6	16.1	40.3	37.4	1.0 (1.5)	1.6 (3.0)	7.0 (2.5)	9.4 (1.6)
Hispanic	15.2	43.5	44.8	35.8	3.2 (1.6)	1.3 (0.6)	8.7 (1.5)	10.0 (1.6)
NH White	22.0	15.8	37.1	40.1	1.0 (2.0)	2.3 (3.8)	7.0 (2.6)	10.5 (1.4)
P-value	0.0159	<.0001	0.0140	0.2405	<.0001	<.0001	<.0001	<.0001
Per Capita Income								
$0-14,999	14.1	25.6	39.3	35.6	1.9 (1.8)	1.8 (2.6)	7.7 (2.2)	9.7 (1.6)
$15-24,999	19.8	19.0	41.0	37.0	1.3 (1.8)	2.0 (3.6)	7.1 (2.6)	9.8 (1.6)
$25-34,999	21.6	17.5	36.3	40.8	1.1 (1.7)	1.8 (3.2)	7.2 (2.6)	10.2 (1.5)
Over $34,000	26.8	17.9	40.8	39.0	1.3 (2.3)	1.8 (3.0)	7.4 (2.7)	10.4 (1.6)
P-value[7]	<.0001	0.0009	0.2776	0.2628	<.0001	0.9687	0.0796	<.0001

[1]Good diet defined as scoring within the top quintile [2]Good diet defined as scoring within the bottom quintile [3]Deriving < 30% of energy from fat [4]Consuming ≥ 5 servings of fruits and vegetables [5]Supermarkets per 100,000 population [6] P-value for differences between using chi square tests for proportions and ANOVA for means [7] P-value for trend

of their home based on GIS measures. New York had significantly more supermarkets per square mile than the other two sites due to the significantly higher population density of this area (65,230 people per square mile in New York vs. 747 and 4,127 in North Carolina and Maryland respectively). However, site differences were not as pronounced when densities were adjusted for population density**.** Minority participants tended to live in areas with lower densities of supermarkets per population than white respondents. Supermarkets per population were not clearly patterned by personal income.

Residents in North Carolina ranked their food environment more poorly than residents of the other sites based both on MESA survey responses and the ecometric measure. No differences in participant reports or in ecometric measures were observed by gender. MESA Hispanic participants ranked their local food environment higher than other racial/ethnic groups but ecometric measures suggested better environments for white participants than for minority participants. MESA participant reports were not clearly patterned by income, but ecometric measures showed a clear income trend with improving environments as income increased.

Table 4.3 shows the relative probability of having a healthy diet or meeting dietary recommendations by the three measures of the local food environment after adjustments for age, sex, race/ethnicity, and per capita income. Adjustment for a categorical measure of income and additional adjustment for education (in 9 categories) had virtually no impact on the results. Participants who had the least supermarkets per square mile within 1 mile of their home were 32% less likely to have a good quality diet as measured by the alternate healthy eating index compared to those with the most stores near their home (Relative Probability (RP) = 0.68 95% CL 0.50, 0.93). Similar results were obtained when assessing the food environment using the survey responses of the participants and the aggregated responses of those who live in the same census tract (RP = 0.60 95% CL 0.43, 0.82 and 0.73 95% CL 0.53, 1.00 for survey and ecometric survey measures respectively).

Participants who lived in areas with the worst spatial availability of supermarkets were also 55% less likely to consume a diet low in fats and processed meats than those who lived in better environments (RP 0.45 95% CL 0.33, 0.63). Characterizing the local food environment using survey responses and the aggregated responses of community

Table 4.3: Adjusted relative probability (RP) and 95% CL of meeting dietary recommendation by different measures of the local food environment[1]

	Local Food Environment Measures								
Diet Indicator	Supermarkets per sq mi			Survey			Ecometric Survey		
p(AHEI = good)[2]	P[3]	RP (95% CL)	% Diff	P	RP (95% CL)	% Diff	P	RP (95% CL)	% Diff
1st Quartile	18.3	0.68 (0.50,0.93)	-31.8	17.7	0.60 (0.43,0.82)	-40.3	17.5	0.73 (0.53,1.00)	-27.4
2nd Quartile	20.0	0.71 (0.51,1.01)	-28.5	22.1	0.76 (0.53,1.08)	-24.2	18.4	0.70 (0.52,0.95)	-29.7
3rd Quartile	19.4	0.69 (0.51,0.95)	-30.7	18.9	0.65 (0.48,0.89)	-34.9	18.2	0.72 (0.54,0.96)	-28.4
4th Quartile	21.4	Referent		25.9	Referent		23.7	Referent	
p(Western = good)[4]									
1st Quartile	13.0	0.45 (0.33,0.63)	-54.8	13.7	0.54 (0.38,0.75)	-46.5	16.5	0.60 (0.43,0.84)	-40.0
2nd Quartile	15.9	0.57 (0.40,0.82)	-42.6	19.4	0.67 (0.46,0.97)	-32.9	21.4	0.83 (0.61,1.13)	-16.7
3rd Quartile	18.0	0.54 (0.40,0.73)	-46.3	24.0	0.82 (0.59,1.12)	-18.4	17.8	0.71 (0.52,0.96)	-29.3
4th Quartile	35.2	Referent		26.9	Referent		24.8	Referent	
p(Fat < 30%)									
1st Quartile	34.6	0.69 (0.52,0.91)	-31.3	34.8	0.80 (0.59,1.08)	-20.0	36.8	0.75 (0.57,0.99)	-25.0
2nd Quartile	39.4	0.83 (0.62,1.13)	-16.7	41.7	1.04 (0.75,1.44)	3.7	41.0	0.99 (0.77,1.29)	-0.5
3rd Quartile	39.8	0.81 (0.62,1.06)	-18.9	42.8	1.18 (0.88,1.56)	17.5	39.6	0.94 (0.73,1.20)	-6.4
4th Quartile	45.7	Referent		39.3	Referent		40.6	Referent	
p(Fruit/Veg > 5 svg/d)									
1st Quartile	38.9	1.08 (0.83,1.40)	7.7	36.7	0.77 (0.58,1.01)	-23.1	35.7	1.07 (0.82,1.39)	6.8
2nd Quartile	38.0	0.98 (0.73,1.31)	-2.3	37.4	0.83 (0.61,1.14)	-16.6	39.9	1.15 (0.90,1.49)	15.5
3rd Quartile	37.4	0.98 (0.75,1.27)	-2.3	39.1	0.86 (0.66,1.13)	-13.7	38.6	1.18 (0.92,1.50)	17.8
4th Quartile	37.4	Referent		41.2	Referent		37.6	Referent	

[1]Adjusted for age, race, gender, and continuous per capita income [2]AHEI: good diet defined as scoring in top quintile [3]P = percent of participants meeting recommendation/ with a good diet [4]Western diet: good diet defined as scoring in bottom quintile

members yielded similar results. Those with poor spatial access to supermarkets were also nearly 31% less likely to meet dietary fat recommendations (RP= 0.69 95% CL 0.52, 0.91). Associations of fat intake with the local food environment based on individual survey responses and aggregated responses of those living in the same area were similar to GIS based measures for the lowest quintile (although not statistically significant) but no clear trend across quartiles was observed. Fruit and vegetable consumption was not associated with food environment measures with the possible exception of the MESA survey measures, for which a weak trend was observed with lower probability of meeting dietary recommendations among persons who reported the worst access.

Because of the different population densities between the three sites, the NY site was overrepresented in the top quartiles of densities of supermarkets per square mile. When densities of supermarkets that were population density adjusted were examined, supermarket densities were still positively associated with dietary outcomes but associations were attenuated and no longer statistically significant as shown in Table 4.4: those living in areas with the worst access to supermarkets were 13-19% less likely to have a good diet and meet dietary fat recommendations than those who lived in areas with the highest densities of supermarkets compared to 31-55% less likely when supermarkets per area were examined (as shown in Table 4.3). Results using site specific quartiles of densities rather than quartiles based on the distribution of densities pooled across sites yielded results that were similar in magnitude and significance to population density adjusted results.

In stratified analyses, there was no consistent evidence across food environment measures that associations differed qualitatively by age (<65 vs. 65 and over), sex, race/ethnicity, per capita income (dichotomized at median), or time spent in neighborhood (dichotomized at median).

4.3 Discussion

Participants who had the least supermarkets per square mile within 1 mile of their home were 31-55% less likely to have a good quality diet depending on the dietary measure used and 31% less likely to meet dietary fat recommendations compared to those with the most supermarkets near their home. Similarly, when assessing the food

Table 4.4: Adjusted relative probability (RP) and 95% CL of meeting selected dietary recommendation for 1st vs. 4th quartile of supermarkets densities[1]

Densities of Supermarkets	Dietary Outcomes		
	p(AHEI = good)	p(West = good)	p(Fat < 30%)
Crude Quartiles[2]	0.68 (0.50,0.93)	0.45 (0.33,0.63)	0.69 (0.52,0.91)
Population Adjusted Quartiles	0.87 (0.66,1.15)	0.81 (0.59,1.11)	0.84 (0.66,1.08)
Site Specific Quartiles	0.79 (0.60,1.03)	0.80 (0.59,1.07)	0.97 (0.76,1.24)

[1]Adjusted for age, race, gender, and continuous per capita income [2] Based on densities of stores pooled across sites

environment using the survey responses of the participants and the aggregated responses of those who live in the same census tract, those who lived in areas with the worst ranked local food environments were 27-47% less likely to have the type of diets associated with worse health outcomes. Associations tended to be slightly stronger for supermarket densities than for the other measures of the food environment. Overall, the consistency of patterns across the three different measures of the local food environment strengthens our inferences regarding associations between the local food environment and diet.

Only a few studies have investigated associations between the local food environment and diet. Many of these used the presence of supermarkets as the key local food environment measure**.** Laraia et al reported that pregnant women living more than 4 miles from a supermarket were half as likely to follow a healthy diet (measured by a composite measure of diet, the diet quality index for pregnancy (DQI-P) which includes servings of grains, vegetables, fruits, folate, iron, calcium, and fat intake, and meal pattern score) as women living within 2 miles of a supermarket (9). Other studies focused on fruit and vegetable consumption and dietary fat intake. Morland et al. found that meeting requirements for fruit and vegetable intake was positively associated with the number of supermarkets in the census tract after controlling for individual-level confounders (relative risk for each additional supermarket in the census tract 1.32 95% confidence interval 1.08, 1.60 for Black Americans and 1.11 95% CI = 0.93, 1.32 for white Americans)(4). In addition, the proportion of blacks meeting dietary recommendations for fat intake was 25% higher among those living in areas with at least one supermarket compared to those living in areas with no supermarket. In one of the only natural experiments of the effect of the food environment on diet to date, Wrigley et al. investigated changes in the consumption of fruits and vegetables associated with the opening of a large food superstore. A before and after survey of 600 people found that people who consumed <2 fruits and vegetables a day increased consumption by 34% after the store opening (11;48). Other investigators have also found that access to supermarkets was positively associated with fruit and vegetable consumption (10;18).

Very few studies have investigated other measures of the food environment. Several studies have found positive associations between the availability of healthy foods as assessed by shelf space in stores and the self reported consumption of healthy foods by residents (49-51). Our study confirms previous work showing a relation between the local food environment and dietary patterns, and demonstrates the robustness of results to different measures of the local food environment.

In our analyses, global measures of dietary quality were more strongly associated with the local food environment than fat intake. Fruit and vegetable intake were not associated with the local food environment. Global measures may be more useful in determining the impact of the food environment on diet because the environment may affect multiple aspects of diet quality. For fat intake and fruit and vegetable intake it may be more relevant to investigate more specific measures like whether the store has low fat foods and fruits and vegetables. Measurement error in fruit and vegetable intake may have also have limited our ability to detect associations.

Due to large site differences in supermarket densities across sites, NY respondents were overrepresented in the highest quartile of supermarket densities. Associations between supermarket densities and diet were similar in direction although weaker in magnitude when population adjusted densities or when site specific quartiles of densities were used. Arguably, when investigating the association of the local food environment with diet, stores per area may be a more relevant measure of availability than stores per population because it is the presence of a store, rather than the number of people it serves, that is likely to affect people's purchases and behaviors. For these reasons, we believe the simple unadjusted supermarket densities provide the most relevant measures. We controlled for key individual-level confounders, but the structure of our data makes it impossible to categorically rule out unmeasured confounding by site.

Determining the appropriate measure to represent the local food environment has been a major challenge in studying the relationship of the local food environment with diet quality. Previous literature focuses mainly on using counts of stores in census tracts imposing artificial boundary limits that may not accurately represent the relevant food environment. In this study we moved beyond prior work by using three different assessments of the local food environment. The use of the density of stores in a 1 mile radius around a participant's home may more accurately characterize the environment than census tracts because it more appropriately reflects what stores are in immediate proximity to each individual participant. Survey measures may offer insight into another dimension of the food environment by providing information on the types of foods that are actually available. A disadvantage of this method is that it may introduce same source bias if food availability and dietary outcome measures are obtained from the same respondents. The use of independent informants, neighbors of participants in this study, to obtain an independent characterization of the food environment avoids this bias. Nevertheless, aggregate survey measures may be limited by sample size with insufficient people surveyed in some areas. A disadvantage of our survey measures is the potential for measurement error in the scales. Each type of measure has its strengths and limitations. The consistency of our findings across measures strengthens our confidence that food availability is indeed associated with dietary quality.

The cross-sectional design of this study does not preclude a reverse causality explanation of results. It is just as logical to think that people's food preferences may influence what types of stores and products are available in neighborhoods as it is to think that the products and stores are available in neighborhoods influence consumption patterns. Therefore, causal conclusions cannot be drawn from this study alone; however, the presence of these cross-sectional associations is consistent with a causal processes which can be investigated more directly in longitudinal and experimental designs.

Results from this study are also limited by the fact that all dietary outcomes were derived from a food frequency questionnaire which may introduce bias into estimates of diet quality through several pathways. Firstly, FFQs may not capture the overall variability of the diet especially in ethnic populations where non traditional diet items may not be included in the survey. The food frequency in this particular study was checked for validity in several racial/ethnic groups and modified specifically to reflect the diet of ethnic populations. Respondents' definitions of serving sizes of foods within the same FFQ may also be highly variable between persons which may introduce measurement error. The caloric content of each food item was assigned by the DietSys Nutrient Analysis program and may not reflect true nutritional content in that foods may be prepared in ways that may add or subtract from the nutritional content. Certain questions contributed to multiple food groups (eg, most mixed dishes were disaggregated into their component parts), whereas other items from the questionnaire constituted a single group because of the high reported intake (eg, coffee), unique attributes with suspected biological effect (eg, avocado and guacamole), or inability to adequately disaggregate all foods included in one line item of the questionnaire (eg, egg salad, chicken salad, and tuna salad). Lastly, FFQs may only reflect a small time period in subjects' typical diet. These problems are characteristic of food frequencies and while troublesome, still allow for the systematic examination of dietary patterns in a large population, the primary advantage of this method

Although our results indicate that persons who live in environments with more resources have better diets, it is still important to note that the majority of people in this cohort including those who live in the best areas do not have a healthy diet. Modifying the food environment may help to improve diet quality in populations that may have poor access to resources, but broader population approaches are also needed to improve dietary quality overall. Future research is needed to evaluate the impact of individual level dietary interventions coupled with interventions that modify the environments where people live in order to identify more effective approaches to stem the tide of obesity in the United States.

4.4 References

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Chapter 5: Conclusion

Using data from multiple economic sources and from the Multi-Ethnic Study of Atherosclerosis (MESA), this project (1) examined associations of a more complete depiction of the local food environment with sociodemographic characteristics of neighborhoods, (2) investigated agreement between various ways of assessing the food environment, and (3) examined the relationship of the local food environment characterized in several different but complementary ways with diet quality.

Results from these analyses indicate that not only are there fewer supermarkets in minority and poor areas echoing previous study results, but also, overall, there are fewer fruit and vegetable markets, bakeries, specialty stores, and natural food stores in these neighborhoods. These results provide empirical support for the often-cited claim that food options differ across neighborhoods, and that lower cost healthy food options may be reduced in poor and minority areas. Adherence to the type of diet that has been associated with a lower chronic disease risk may consequently be more difficult or at least more inconvenient and may ultimately contribute to racial and social disparities in obesity and related chronic conditions. The location of food stores depends on a complex set of factors including marketing decisions of large corporations, the perception of the market by small businesses, consumer demand and purchasing power, competition, local regulations, and also local culture. Thus changing the local food environment will require intersectorial approaches. Moreover, not all poor or minority neighborhoods have unhealthy food environments; in some instances poor, ethnic neighborhoods may offer more healthy choices than wealthier areas. Identifying the processes that allow poor and minority neighborhoods to attract and retain healthy food choices may suggest important avenues for intervention.

Results from this series of studies also addressed one of the major challenges in studying the effect of the environment on diet; measurement of the local food environment. While most studies have used the presence of supermarkets in administrative areas like census tracts as a proxy for the availability of healthy foods, this study investigated the interrelation of two different but complementary ways of characterizing the local food environment. GIS based characterizations capture the objective presence of various types of stores in areas and may correspond to areas more relevant to food purchasing behavior. Survey based characterizations on the other hand may more appropriately measure the underlying construct of interest, what healthy foods residents recognize as available in their neighborhoods. Measures of the availability of healthy foods in neighborhoods based on the survey responses of residents were found to be positively associated with GIS derived densities of supermarkets and, in one of the three regions, with densities of smaller stores. Investigating alternative ways of representing the local food environment may help to create more representative pictures of what resources are available to people near their homes and provide more insight into potential viable mechanisms for intervention. These results indicate that survey and GIS measures are associated but not synonymous so that these measures separately may provide complementary information when measuring the impact of the local food environment on diet.

The last component of the project built upon previous literature by examining associations of various dietary behaviors including a priori and empirically derived indices of diet quality with three different but complementary methods of characterizing the local food environment: (1) GIS-derived data on the location of supermarkets (2) characteristics of the local food environment reported by MESA participants and (3) a measure of the local food environment derived by aggregating responses of other residents of MESA neighborhoods. Consistent with findings from previous studies, results from this study indicate that having better access to resources was associated with meeting dietary fat recommendations and following the types of diets associated with better health outcomes. Most importantly, regardless of how the quality of the local food environment was assessed, diet quality was consistently better among those that lived in areas with better environments.

Global measures of dietary quality were more strongly associated with the local food environment than fat intake and fruit and vegetable intake and overall may be more useful in determining the impact of the food environment on diet because the environment may affect multiple aspects of diet quality. For fat intake and fruit and vegetable intake it may be more relevant to investigate more specific measures like whether the store offers a variety of low fat foods and fruits and vegetables at appealing prices. The few studies that have investigated associations between the local food environment and diet have primarily relied on the presence of supermarkets as the key local food environment measure**.** This study confirms previous work showing a positive relationship between the local food environment and dietary patterns, and demonstrates the robustness of results to different measures of both the local food environment and dietary indicators.

The dietary consequences of neighborhood differences in food stores depends on multiple factors including the types of foods available at the stores and the extent to which residents rely on local stores for shopping. If small grocers do indeed offer less healthy foods at higher costs than supermarkets and other types of stores are not present to make up for the lack of supermarkets in areas (as suggested by this data), residents of poor and minority neighborhoods who depend on local stores as their main source of food may be nutritionally disadvantaged. However, it is important to emphasize that the relationship between type of store and products offered is by no means fixed. It is perfectly plausible that a multiplicity of varied small stores can offer the range of food products necessary for a healthy diet. There are also important trade offs between large supermarkets (which often require large parking lots) and small stores in terms of automobile traffic and consequences for neighborhood walkability and street life (including social interactions between neighborhoods), all of which have may have health consequences. For example, poor and minority neighborhoods tend to have larger numbers of small grocery stores, which may have substantial secondary benefits over small numbers of very large supermarkets in terms of street life, social interactions, and traffic especially in regions like the New York site where neighborhoods are more walkable and car ownership is rarer.

In the US context, the presence of a supermarket may be an adequate marker for availability of affordable healthy foods. However, it does not necessarily follow that improving the food environment of disadvantaged communities requires only increasing the number of large supermarkets. While the presence of supermarkets in neighborhoods has been shown to improve the availability of healthier foods, participants in this cohort who had the best access to supermarkets reported that the selection and quality of produce and low fat foods was only 16% higher than those who lived in areas with worst access. Furthermore regardless of whether the quality of the local food environment was assessed by densities of supermarkets in the area or what healthy foods participants, or their neighbors, report as available near their homes, diet quality was consistently better among those living in neighborhoods with more resources. Several studies have found positive associations between the availability of healthy foods as assessed by shelf space in stores other than supermarkets in areas and the self reported consumption of healthy foods by residents (1-3). Improving the environment may also not require building supermarkets in areas because almost all participants in this study reported that the majority of their household food shopping was done in a supermarket. While the spatial availability of stores may be an important first step in encouraging populations to follow a healthier diet, other factors like the aesthetic quality of supermarkets, the distance and cost to travel to these stores, and the variety, convenience to prepare, and cost of healthy foods offered by the stores may also need to be addressed in future research in order to help the general population make choices that are consistent with dietary recommendations.

Limitations

Measuring the local food environment

Determining the appropriate measure to represent the local food environment has been a major challenge in studying the relationship of the local food environment with diet quality in populations. Characterizing the local food environment requires specification of two domains: the geographic size and definition of the area to be assessed and the actual construct to be measured. Previous literature focus traditionally on using counts of stores in census tracts which imposes artificial boundary limits and assumes all stores offer the same options which may not accurately represent the food environment.

This study moved beyond prior work by using three different assessments of the local food environment.

GIS measures based on types of stores present

Using an alternative definition of the food environment as the density of stores in a 1 mile radius around a participant's home may more accurately characterize the environment than census tracts because it may more appropriately reflects what stores are in immediate proximity to each individual participant. Being able to specify smaller boundaries for neighborhoods than census tracts is a key strength of this method. However, the GIS measures used in this study have several important limitations. These measures also only represent the presence of different types of stores in areas as do more traditional measures, not what products they offer. Previous work has shown that the quality of the same type of store can vary substantially by demographic features of the surrounding neighborhood (4). A recent study by Horowitz et al found that only 18% of bodegas, or small grocers, in a minority neighborhood carried a selection of healthy foods compared to 58% of bodegas in a predominantly white area. Additionally, because primary data collection across the very broad areas that were studied was not feasible, these measures were derived from a commercial database established for marketing purposes rather than data collected for research purposes. Compared to a federal economic census, this data source reliably captured the number of food stores present in the three study areas. Agreement between specific types of stores however was much lower likely caused by inherent differences in the classification methods used by the standard NAICS system used by the census and the system created by InfoUSA. Because of their utility in the examination of differences in the local food environment (and their potential health consequences) across large areas in a systematic fashion, measures derived from commercial databases remain very useful. Informal food sources such as street vendors and roadside stands which may be important in certain types of neighborhoods were also not captured in these types of data sources and consequently in GIS measures.

Survey measures

Unlike locational measures, survey measures may offer insight into the types of foods that people recognize as available in their neighborhoods. Also unlike the GIS derived densities, people can report on a less stringent definition of neighborhood. Respondents in this study were asked to think of their neighborhood as the area within a mile of their home but there were no definite demarcated boundaries as with the GIS measures. On one hand this allows respondents to respond regarding the area they perceive as their neighborhood but this also means that respondents may be referring to areas of very different sizes in their reports. Another disadvantage of this method is that it may introduce same source bias if food availability and dietary outcome measures are obtained from the same respondents. The use of independent informants, neighbors of participants in this study, to obtain an independent characterization of the food environment may bypass this bias. Nevertheless, aggregate survey measures may also be limited by sample size with insufficient people surveyed in some census tracts within the MESA sites. Measurement error may also cause fluctuations in these measures because respondents may misestimate the geographic bounds of one mile and respondents' views of their local food environment may be either positively or negatively influenced by various individual experiences and personal behaviors. Each type of measure has its strengths and limitations. The consistency of our findings across measures strengthens our confidence that local food environment is indeed associated with dietary quality.

Measuring Diet

Results from this study are also limited by the fact that all dietary outcomes were derived from a food frequency questionnaire which may introduce bias into estimates of diet quality through several pathways. FFQs may not capture the overall variability of the diet and respondents' definitions of serving sizes of foods within the same FFQ may also be highly variable between persons. Caloric content of each food item was assigned by the DietSys Nutrient Analysis program and may not account for different food preparation practices. Certain questions contributed to multiple food groups (eg, most mixed dishes were disaggregated into their component parts), whereas other items from the questionnaire constituted a single group because of the high reported intake (eg, coffee), unique attributes with suspected biological effect (eg, avocado and guacamole), or inability to adequately disaggregate all foods included in one line item of the questionnaire (eg, egg salad, chicken salad, and tuna salad). Lastly, FFQs may only reflect a small time period in subjects' typical diet. These problems are characteristic of food frequencies and while troublesome, still allow for the systematic examination of dietary patterns in a large population, the primary advantage of this method.

Cross-sectional design

Another limitation of this study is that it is restricted to a cross sectional analysis. A major critique of this type of design is that it does not preclude a reverse causality explanation of results. It is just as logical to think that people's food preferences may influence what types of stores and products are available in neighborhoods as it is to think that the products and stores are available in neighborhoods influence consumption patterns. Therefore, causal statements cannot be generated from this particular study; however, this study will contribute to the literature by providing empirical evidence to assist in developing potential hypotheses about mechanisms through which the environment can affect consumption patterns which can be investigated by longitudinal and experimental designs.

Accounting for individual-level confounders

Both measures of the local food environment and dietary patterns are patterned by various individual characteristics including, race/ethnicity, socioeconomic status, age, and gender. Adjustments for these variables were made in analyses to rule out these covariates as alternative explanations for the observed associations between the local food environment and diet. Covariates were examined as both categorical and continuous variables in models where possible to assure that they were adequately controlled for. Additional adjustments for education, a frequently used proxy for socioeconomic status in studies, did not affect results.

Generalizability of the results to other regions

Most previous studies are limited to small geographic areas effectively limiting the generalizability of results to other regions. A key strength of this series of studies is that it encompassed three very large and geographically diverse areas. Regional variation in associations were also examined and documented whenever appropriate. Overall and site-specific results from this broad study may therefore be more generalizable to other US cities than prior work. However associations observed in this study which geographically focused on primarily urban areas may not hold as true in more rural areas in the US.

Public Health and Policy Implications

The infrastructure of the local food environment is yet another feature of the built environment that varies substantially across neighborhoods and may contribute to disparities and social inequalities in health. Accurate description of resources available to areas and area differences in the local food environment is an important first step. However, future research will need to move beyond descriptive studies to investigations of how best to effect change in the local food environment and studies of whether changes in the local food environment are associated with changes in residents' diets. These types of studies will also have to confront issues of regional variation which were sometimes discussed only briefly in these series of studies to focus more on the more important goal of linking the environment to healthier diets. In sites like New York, having smaller stores in certain areas like Hispanic neighborhoods may be just as beneficial as having supermarkets because of the variety and cost of culturally specific items offered by these smaller types of stores. Exploration of how smaller stores may contribute to healthier diets in different regions of the country warrant continued exploration.

While these studies indicate that spatial inequities in the local food environment exist and are associated with diet quality, it is still important to note that the majority of people in this cohort including those that live in the best areas do not have a healthy diet. Modifying the food environment may help only to reduce racial and social health disparities in overweight and obesity. Improving availability of healthy foods in populations that have poor access to resources may improve diet quality in these groups even ideally only to the point that they match the levels of those who live in the best environments which is still appallingly low. In the only natural experiment to date, adding a supermarket in an area that was previously considered a food desert in England resulted in a 34% increase in fruit in vegetable intake in only people with the worst diets. In the US, improving the availability of stores and healthy foods in the environment is also unlikely to be sufficient to significantly change long held dietary habits. Providing supportive environments for healthy eating is only a first step towards a healthier population. There are complex interactions of what people chose to eat with social, cultural, and economic factors in addition to environmental influences examined in these series of studies. Environmental interventions are thought to be more promising for shifting eating patterns than interventions targeting individual dietary behaviors but empirical evidence is still needed to support this premise. Studies in captive audiences where few other choices are available such as worksites and schools have been found to be relatively effective in encouraging healthier habits while interventions at grocery stores have not been as convincing (5;6). In a recent review of 10 grocery store interventions, half saw increased sales of targeted items and the other half reported no significant increase in sales with various informational marketing campaigns with no change in dietary indicators in the two studies that collected information on diet. The authors concluded that the focus needs to shift to true environmental interventions that focus on access, availability, and incentives to promote healthier choices in populations rather than on informational strategies that attempt to prompt behavior change (5). While ignoring the role the environment may play in encouraging healthier eating habits would be sisyphean, essentially expecting success while people are struggling uphill with their environments to follow a healthier lifestyle, not recognizing that a supportive nutritional environment is only one component of an overall plan to encourage healthier habits may also inevitably lead to failed interventions. Culturally and socially tailored interventions that appeal to individual backgrounds are also important tools in encouraging individuals to follow a healthier diet.

Future research is needed to evaluate the impact of individual level dietary interventions when they are coupled with components that specifically address the context of where people live to develop and apply more effective approaches to stem the tide of obesity in the United States. Collaboration between community organizations, economic development planners, and public health researchers will be essential in moving this agenda forward.

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