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Neighborhood Socioeconomic Deprivation and Minority Composition Are Associated with Better Potential Spatial Access to the Ground-Truthed Food Environment in a Large Rural Area[1,2]

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Abstract

Little is known about spatial inequalities and potential access to the food environment in rural areas. In this study, we assessed the food environment in a 6-county rural region of Texas (11,567 km^2) through ground-truthed methods that included direct observation and on-site Global Positioning System technology to examine the relationship between neighborhood inequalities (e.g., socioeconomic deprivation and minority composition) and network distance from all 101 rural neighborhoods to the nearest food store (FS). Neighborhood deprivation was determined from socioeconomic characteristics using 2000 census block group (CBG) data. Network distances were calculated from the population-weighted center of each CBG to the nearest supermarket, grocery, convenience, and discount store. Multiple regression models examined associations among deprivation, minority composition, population density, and network distance to the nearest FS. The median distance to the nearest supermarket was 14.9 km one way (range 0.12 to 54.0 km). The distance decreased with increasing deprivation, minority composition, and population density. The worst deprived neighborhoods with the greatest minority composition had better potential spatial access to the nearest FS. For >20% of all rural residents, their neighborhoods were at least 17.7 km from the nearest supermarket or full-line grocery or 7.6 km from the nearest convenience store. This makes food shopping a challenge, especially in rural areas that lack public transportation and where many have no vehicular access. Knowledge of potential access to the food environment is essential for combining environmental approaches and health interventions so that families, especially those in rural areas, can make healthier food choices. J. Nutr. 138: 620–627, 2008.

Introduction

The achievement and maintenance of good nutritional health is especially vital for low-income rural populations. Typically, these populations are disproportionately minority and poor, have restricted access to health care and other resources due to the spatial inequality of living in rural or impoverished areas, and face greater vulnerability to poor nutritional health, obesity, increased morbidity, and a greater burden of disease (1–4).

The availability of healthy foods in the home (e.g., fruits, vegetables, low-fat dairy products, grains, and foods low in total and saturated fat, cholesterol, sodium, and sugar) depends to a large extent on the potential spatial (i.e., geographic) access of a household to the food environment; that is, the number, type, size, and distance of food stores (FS)[6] to the neighborhoods where people reside (5–17).

The inclusion of environmental approaches with health interventions requires an accurate determination of potential spatial access to FS, which relies on true identification of store types that make food available for consumer purchase and precise locational point data (18). Although ground-truth surveys of FS, which involve an in-person, neighborhood street canvass and enumeration of FS, may be the most accurate assessment of the food environment, the preponderance of published work on

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[6] Abbreviations used: BVFEP, Brazos Valley Food Environment Project; CBG, census block group; FS, food store; GPS, Global Positioning System; GT, ground-truthed; HD, high deprivation; HM, high minority composition; LD, low deprivation; LM, low minority composition; MD, medium deprivation; MM, medium minority composition; PL, public lists; SF-3, 2000 U.S. Census Summary File 3; UC, urban clusters.

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food access utilizes public records or commercially available business listings to identify select types of FS (11,14,15,17,19–24). Little is known about the degree to which the use of public data within a rural area may misrepresent the food environment through overstatement and/or understatement of FS present. Additionally, determination of locational points of public or commercially available data customarily uses a commercial vendor or software with a street database, which can result in greater positional errors and address inaccuracies, particularly in rural or poorer areas. (25,26). As part of ground truthing to pinpoint exact locations, locational point data are determined using Global Positioning System (GPS) technology, which is considered the gold standard for both urban and rural areas (26).

Researchers have shown that neighborhood disadvantages may underlie the spatial inequality that residents, especially minority populations in urban areas, confront with regard to increased obesity risk and access to healthful foods (12,14,19, 23,27–30). Others have recognized the spatial inequality that persists between families in rural communities and families in urban areas (31,32). Without easy geographic access to supermarkets or full grocery stores, individuals either have to pay higher travel costs to reach a supermarket or are only able to shop at convenience or small grocery stores and pay higher prices for limited selections of food products (9,17,22).

Because little is known about spatial inequalities and potential spatial access to FS within rural areas, this study expands our understanding of potential spatial access to the rural food environment by *1*) identifying and geocoding all FS in a 6-county rural region in Texas, using ground-truth surveys: direct observation and on-site GPS; *2*) determining the distribution of network distances from the neighborhood center to the nearest supermarket, supermarket or grocery store of any size, convenience store, and discount store in all 101 neighborhoods; and *3*) examining the relationship between neighborhood inequalities (e.g., socioeconomic deprivation and minority composition) and network distance to the nearest FS.

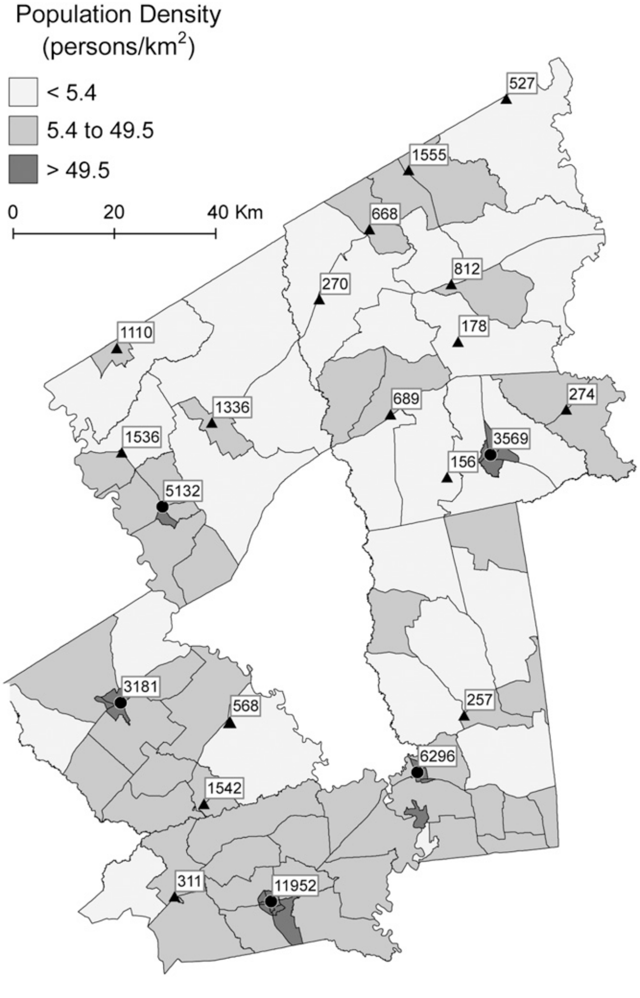

FIGURE 1 Map of 101 neighborhoods (CBG) in rural study area. Boxed numbers indicate population for each of the UC and smaller towns.

Materials and Methods

Rural setting and sample. In this study, we used data from the 2006 Brazos Valley Food Environment Project (BVFEP), which was approved by the Institutional Review Board at Texas A&M University, and the decennial 2000 U.S. Census Summary File 3 (SF-3). The BVFEP is a comprehensive study of the rural food environment that used ground-truth methods in all 101 census block groups (CBG) of 6 rural counties in the central Texas Brazos Valley region; these counties were designated as rural based on population density (persons/km^2), which ranged from 5.5 to 19.3 (33–35). The 6 counties (**Fig. 1**) included 5 urban clusters (UC; population >2500), several smaller towns (population 156–1555), and many unincorporated areas. The rural region covered a land area of 11,567 km^2 (258 km^2 in 25 UC CBG) and was home to 119,654 people (35). There were no regular public transportation services in any of the 6 rural counties, including fixed route, commuter, or taxi services (36,37). Characteristics of rural county residents of the Brazos Valley were consistent with profiles of residents of other rural areas: a significantly older population, less education, lower socioeconomic status, higher rates of chronic disease and mortality, less insurance coverage, and lower access to health care services (33). CBG, which are the smallest units of census geography for which the detailed "long-form" social and economic data from the census are tabulated, were selected to define a neighborhood (14,38,39).

Defining FS. FS were defined using a modified version of the 2002 North America Industry Classification System definitions (40). FS, which retail a general line of food products, include supermarkets, full-line grocery stores, convenience stores or food marts (with and without gasoline pumps), discount stores (general merchandise and some perishable and nonperishable foods), beverage stores (with some perishable and nonperishable foods), pharmacies and drug stores (with some perishable and nonperishable foods), and specialty FS (e.g., meat markets, fish and seafood markets, fruit and vegetables markets, and markets with bakeries not for immediate consumption) that are fixed or mobile.

Direct measurement of the rural food environment. Considering that direct observation (i.e., ground truthing) is the ideal methodology (15), an approach was developed for the BVFEP to directly observe, identify, and geocode (i.e., assign geographic coordinates to specific locations) all FS within the study area. On-site measurement of locational points was deemed necessary because existing road files that are often used to geocode locations from an address may be an inaccurate representation of current roads in rural areas. On-site measurement ensured accuracy and identification of 100% of the locations.

Observers were trained and ground-truth protocols were pretested that included the following components: *1*) identify and classify an FS; *2*) determine latitude and longitude for the specific location of each FS; *3*) photograph the location; and *4*) complete a "windshield survey" of the characteristics of each FS observed from the outside. All highways (Interstate, U.S., and State), farm-to-market roads, and city or town streets/roads within the study area were systematically driven. The geographic coordinates (latitude and longitude) for the specific location of each FS were determined by a camera-based GPS. Geographic position was measured in front of each FS with a Bluetooth Wide Area Augmentation System–enabled portable GPS receiver after at least 4 satellite signals were detected; the World Geodetic System 1984 datum was used.

Locational data were then converted utilizing GPS-Photo Link into an Environmental Systems Research Institute-compatible shape file.

Following the completion of FS identification through ground truthing, a public listing of names and addresses of all FS was acquired from local/area telephone directories, Internet telephone directories, and a list of Current Food Establishment Group Firms from the Texas Department of Agriculture. The list of 208 FS identified through ground-truth methods was compared with the public listing of 169 FS for the study area. Roads were again driven, looking specifically for the 37 (22%) FS that appeared in public data but were not identified during ground truthing. At the completion of this "revisit," an additional 5 FS (3 convenience stores, 1 discount store, and 1 specialty FS) were identified and GPS locational points were collected.

Potential spatial access of FS. Distance measures from a predefined area (e.g., CBG or census tract), primarily in urban-based studies, use the geographic center or centroid to represent individuals living in the center of the neighborhood or area (12,14,28). Because CBG in rural areas are generally much larger than CBG in urban areas, the geographic center may not accurately represent the population center. Therefore, we chose the population-weighted centroid in a CBG to represent the population center of the CBG (41). Using the SF-3 that provides the total population for census blocks within CBG, the population-weighted centroid for each CBG was calculated using the ArcGIS Desktop tool Mean Center (Version 9.2, Environmental Systems Research Institute). This tool constructs the CBG mean center based on the mean-weighted x and y values of the block population centroids. The network distance along the road network to the nearest FS was calculated between paired point data (the population-weighted CBG centroid and nearest corresponding FS within the study area). Network distance was calculated with ESRI's Network Analysis extension in ArcInfo 9.2, which computed the distance along the road network to the geographic position measured in front of each FS. Separate network distances were calculated to the nearest large supermarket, supermarket/grocery store regardless of size, convenience store, and discount store.

Neighborhood socioeconomic deprivation. The socioeconomic measures of 7 CBG were extracted from the SF-3 for the study area, which represented neighborhood unemployment (persons age 16 y and older in the labor force who were unemployed and actively seeking work), poverty (persons with incomes below the federal poverty line), low education attainment (persons age 25 y and older, with less than a 10th-grade education), household crowding (occupied households with more than 1 person per room), public assistance (households receiving public assistance), vehicle availability (occupied housing with no vehicle available), and telephone service (occupied housing with no telephone service).

Using established procedures (42–46), CBG data from the 6 rural counties were merged and a factor analysis, using the iterated principal factor method (Release 8, 2003, Stata Statistical Software), was constructed to reduce the number of linear combinations and to identify an overall index of neighborhood socioeconomic deprivation. There was 1 factor (eigenvalue 3.2) that was identified and provided item loadings (in parenthesis), which were used to weight each variable's contribution to the deprivation summary score (42,44,45): unemployment (0.43), poverty (0.90), education (0.61), crowding (0.69), public assistance (0.56), vehicle (0.81), and telephone (0.58). The internal consistency of this measure was good (Chronbach's $\alpha = 0.82$). The area-level deprivation index was standardized by dividing the index by the square of the eigenvalue (42,47). Based on the distribution of deprivation scores, a 3-category neighborhood socioeconomic deprivation variable was constructed: low deprivation (LD, highest overall socioeconomics and lowest quartile of deprivation scores), medium deprivation (MD, middle 2 quartiles), and high deprivation (HD, lowest overall socioeconomics and highest quartile of deprivation scores). CBG measures of socioeconomic position meaningfully summarized important aspects of the specified area's socioeconomic conditions and provided data that can be compared over time and across regions (48).

Statistical analysis. All statistical analyses were performed using Stata Statistical Software Release 8; $P < 0.05$ was considered statistically significant. Distances from the population-weighted centroid of each CBG to the nearest FS (supermarket, supermarket or full-line grocery store, convenience store, and discount store) were calculated. The ground-truthed (GT) method for identification of FS was compared with public lists (PL) of FS by comparing frequencies and testing for equalities in mean, median, and distribution of distance measures, using Student's *t* test and Wilcoxon matched-pairs signed-ranks test (46). Because geographic centroids are commonly used in urban areas, equality of means, medians, and distributions of calculations between population-weighted centroids and geographic centroids were compared using the tests above (12,14).

Tests for trend were estimated across categories of increasing deprivation and minority composition using *nptrend*, which performs the nonparametric test for trend across ordered groups (49). Finally, multivariable regression models were individually fitted, using robust (White-corrected) SE, to determine the relationship of neighborhood measures (neighborhood deprivation, minority composition, interaction between neighborhood deprivation and minority composition, and population density) to the network distance to the nearest supermarket, supermarket/grocery store, convenience store, and discount store. The *robust* command in Stata corrects SE for heteroscedasticity of unknown form. Afterward, stratified models were estimated separately for each category of population density.

Results

GT rural food environment. There were 213 FS identified and geocoded in the rural study area: 23 supermarkets or grocery stores, 154 convenience stores, 20 discount stores, 3 beverage stores, and 13 specialty FS. Of the specialty FS, there were 4 meat or fish markets, 3 fixed-location fruit and vegetable stores, 1 bakery, and 2 health FS. PL provided the names and addresses for 169 FS. Compared with GT FS, 147 FS from PL could be verified and 32 (18.9%) could not be verified, even after further attempts to locate the names and addresses through direct observation, for several reasons: address did not exist, not a retail FS, out of business and closed, residence with no apparent food business, and not in business and replaced by new type of business. Of the 213 FS, 64% were identified through ground truthing and PL; 35.7% ($n = 76$) were only GT identified. These 76 locations included 6 supermarkets/full-line grocery stores (26% of the 23 supermarkets/grocery stores), 56 convenience stores (36% of 154 convenience stores), 4 discount stores (20% of 20 discount stores), 2 beverage stores, and 8 specialty FS (all 3 fruit/vegetable stores). Of the 23 supermarkets or grocery stores, 11 were large/very large chain supermarkets (including 1 supercenter) and 12 were small or medium full-line grocery stores. Of the 11 supermarkets, 9 were located in 5 UC; 3 of the 12 grocery stores were in 2 UC.

Comparing the use of GT FS with PL FS, mean, median, and distributions of distances from the same neighborhoods were different ($P < 0.001$). For example, the median distance to the nearest supermarket was 14.9 km using GT and 22.0 km using PL; to the nearest supermarket or grocery store, the distance was 8.4 km (GT) and 14.5 km (PL). In almost 34% ($n = 34$) of the neighborhoods, distance to the nearest supermarket was overestimated from 10.5–70.1 km when using FS identified from PL compared with GT; the distance to the nearest supermarket or grocery store was overestimated in 34 CBG (2.0–70.1 km); and the distance to the nearest convenience store was overestimated in 12.9% ($n = 13$) of CBG (range 1–24.2 km).

Neighborhood characteristics. The distribution of socioeconomic characteristics, minority composition, population, land area, and population density (persons/km^2) was estimated across

TABLE 1 Neighborhood characteristics and potential spatial access to FS[1]

	Mean ± SD	Median	Minimum	Maximum
Socioeconomic characteristics, %				
Unemployment	2.8 ± 1.9	2.4	0	8.8
Residents in poverty	16.0 ± 9.6	14.0	0	57.4
<10th-grade education	15.2 ± 7.2	14.2	0	39.8
Crowded households	5.7 ± 5.1	4.5	0	26.4
Public assistance	2.9 ± 3.0	2.2	0	14.2
Households with no vehicle available	8.8 ± 7.9	6.6	0	38.0
Households with no telephone	4.9 ± 3.9	4.2	0	18.2
Minority composition, %				
African American residents	17.7 ± 15.3	15.1	0.3	74.5
Hispanic residents	11.4 ± 8.7	8.8	0	43.1
Combined African American and Hispanic residents	29.1 ± 20.0	24.6	3.6	89.8
Population	1135.3 ± 517.9	1047.0	13.0	3204.0
Land area, *km^2*	115.8 ± 106.7	99.0	0.7	531.9
Population density, *persons per km^2*	136.6 ± 291.5	9.5	0.7	1332.0
Food environment potential spatial access, *km*				
Nearest supermarket	16.0 ± 13.6	14.9	0.12	54.0
Nearest supermarket/grocery store	11.3 ± 10.1	8.4	0.06	39.4
Nearest convenience store	5.0 ± 4.1	4.5	0.03	16.5
Nearest discount store	12.8 ± 10.5	13.3	0.25	38.8

[1] Values calculated for each CBG (*n* = 101) in the study area.

the 101 rural CBG (**Table 1**). The distribution of neighborhood population density (persons/km^2) was used to determine 3 categories of population density and serve as an indicator of rurality (Fig. 1): low (lowest quartile of population density and highest degree of rurality), medium (middle 2 quartiles of population density), and high (highest quartile of population density and lowest degree of rurality). In data not shown, the proportion of each of the 7 socioeconomic characteristics present in the CBG increased with greater overall neighborhood socioeconomic deprivation, proportion of minority residents, and population density ($P < 0.001$). For example, the median percentage of occupied households with no vehicle available increased with greater neighborhood deprivation (LD, 3.4%; MD, 6.8%; and HD, 14.9%), greater percentage of minority residents [low minority composition (LM), 3.8%; medium minority composition (MM), 7.2%; and high minority composition (HM), 13.4%], and increased population density (low, 5.4%; medium, 6.3%; high, 11.8%).

Potential spatial access to the rural food environment. Distances calculated from the geographic centroid were greater ($P < 0.001$) than those calculated from the population-weighted centroid (data not shown). These differences (maximum of 7.4 km) were observed in 70.3–76.2% of CBG. When a test for trend (data not shown) across ordered groups was performed, distance to the nearest FS decreased ($P < 0.001$) with increasing neighborhood socioeconomic deprivation, with increasing minority composition, and with increasing population density (persons/km^2). Distance from the population-weighted centroid to the nearest FS varied by type of FS, neighborhood deprivation, and minority composition (**Table 2**). Median distances to the nearest FS were calculated by level of population density and plotted for high (**Fig. 2**) and medium (**Fig. 3**) population density neighborhoods. Using 2000 U.S. Census data, >20% of all rural residents lived in neighborhoods that were ≥24 km one way from the nearest supermarket, ≥17.7 km from the nearest supermarket or full-line grocery, or ≥7.6 km from the nearest convenience store (data not shown). A map of the study area was produced to include 3 layers of data that were based on SF-3 and GPS for FS: neighborhood socioeconomic deprivation, neighbor-

TABLE 2 Median and interquartile distance to nearest FS by neighborhood deprivation and minority composition

	LM			MM			HM			All minority		
	Median	25%	75%	Median	25%	75%	Median	25%	75%	Median	25%	75%
						Distance in km						
Supermarket												
LD	21.4	9.0	33.8	9.9	3.2	17.6	17.6	8.2	27.1	17.4	6.3	29.7
MD	28.5	16.7	32.3	17.8	7.8	21.3	9.7	5.3	10.7	18.1	9.2	29.4
HD	0	0	0	7.3	2.0	30.4	1.6	1.2	4.4	2.0	1.2	12.0
All deprivation	25.3	14.9	33.2	17.1	6.3	21.3	2.2	1.2	9.7	14.9	2.2	24.4
Supermarket/grocery												
LD	15.9	9.0	26.1	9.5	3.2	17.3	17.6	8.2	27.1	14.5	6.3	21.3
MD	20.2	14.9	23.1	8.7	5.6	17.4	8.4	5.3	10.7	12.8	6.1	18.3
HD	0	0	0	2.0	0.5	6.3	1.3	1.1	3.2	1.4	0.9	3.2
All deprivation	17.8	11.7	23.8	7.6	2.1	17.1	1.7	1.2	8.2	8.4	1.8	17.6
Convenience store												
LD	4.8	2.4	8.9	4.2	2.2	10.5	6.7	6.5	6.9	4.8	3.4	9.2
MD	6.3	3.8	8.9	5.9	4.0	7.5	5.4	4.0	9.5	5.9	3.9	8.2
HD	0	0	0	1.1	0.5	2.9	0.6	0.1	1.2	0.7	0.2	2.3
All deprivation	5.5	3.4	8.9	5.4	1.4	7.5	1.0	0.3	5.4	4.5	1.0	7.5
Discount store												
LD	16.7	8.5	25.9	9.8	3.2	17.5	17.9	8.2	27.6	15.6	4.9	21.8
MD	22.8	17.0	27.3	14.7	6.3	18.2	7.9	5.2	10.7	15.5	6.9	22.2
HD	0	0	0	7.5	1.8	27.7	1.7	1.2	3.8	2.0	1.2	12.4
All deprivation	20.4	14.8	27.3	13.3	2.7	18.4	2.1	1.3	8.2	13.3	2.0	20.7

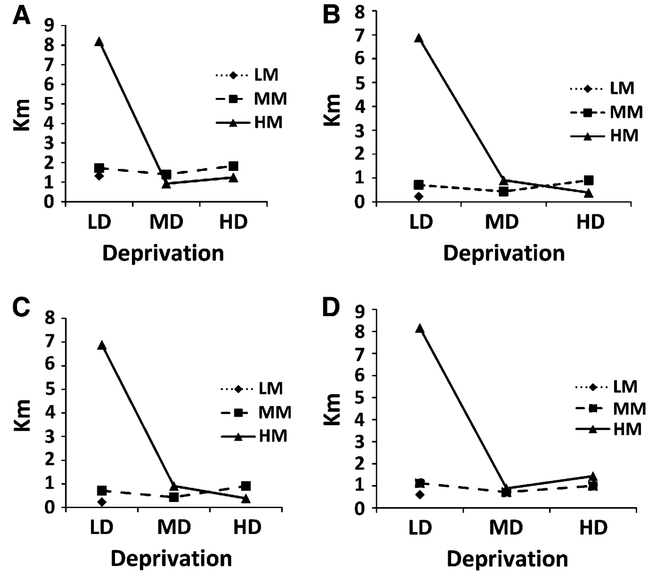

FIGURE 2 Median distance to the nearest supermarket (*A*), supermarket/grocery store (*B*), convenience store (*C*), and discount store (*D*) for high population density neighborhoods ($n = 25$), by percentage of minority composition and level of socioeconomic deprivation.

hood minority composition, and location for supermarkets and grocery stores (**Fig. 4**).

Neighborhood characteristics and potential spatial access to FS. Independent of population density, neighborhoods that were both HM and HD had the best potential spatial access to the nearest supermarket, supermarket or grocery store, and discount store; this was followed by neighborhoods that were both HM and MD for supermarkets and discount stores (**Table 3**). Restricting these analyses to high population density neighborhoods demonstrated that HM/HD neighborhoods continued to have the best spatial access, followed by HM/MD neighborhoods, to all 4 types of FS (data not shown).

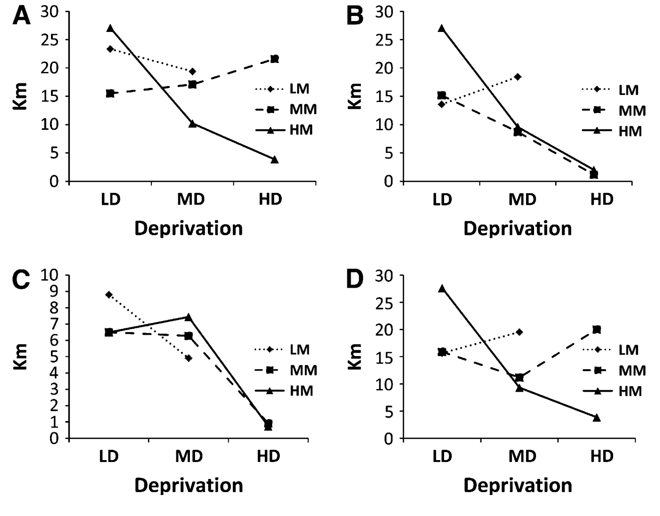

FIGURE 3 Median distance to the nearest supermarket (*A*), supermarket/grocery store (*B*), convenience store (*C*), and discount store (*D*) for medium population density neighborhoods ($n = 49$), by percentage of minority composition and level of socioeconomic deprivation.

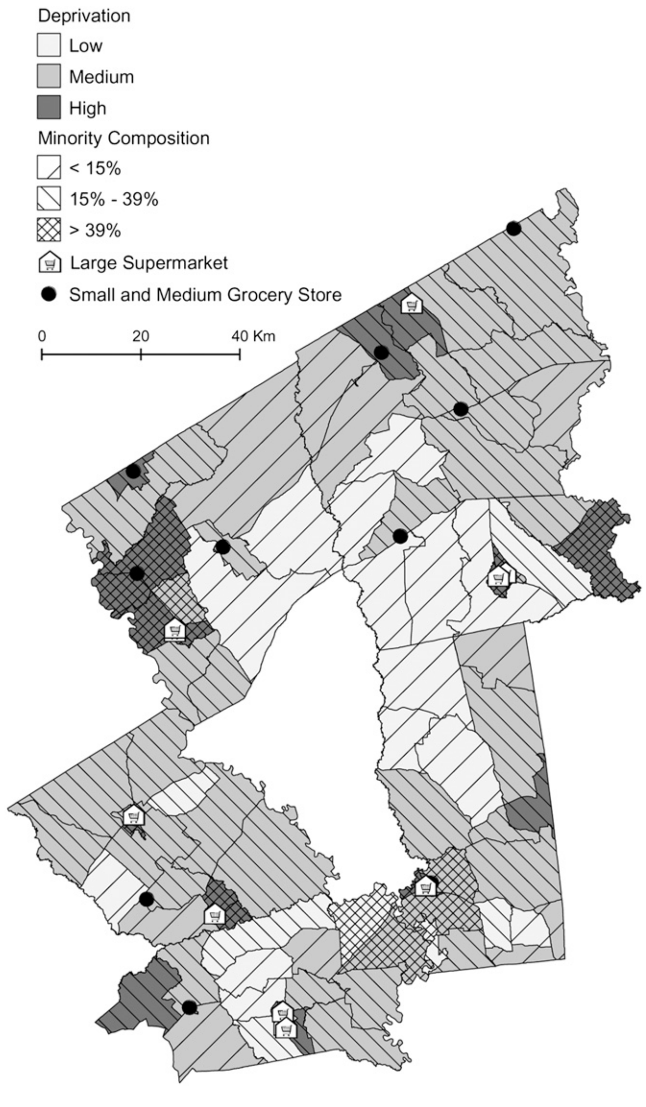

FIGURE 4 Map of supermarkets and grocery stores in the study area. Neighborhood socioeconomic deprivation and minority composition are indicated for the study area by neighborhood.

Discussion

This study extends our understanding of spatial access to the food environment and is apparently the first study, to our knowledge, that evaluates the measurement of the rural food environment and examines the relationship between neighborhood characteristics and potential spatial access to different types of FS. Our analyses not only revealed that neighborhoods with the greatest socioeconomic and racial disparity have better access to supermarkets, grocery stores, convenience stores, and discount stores, but also that they have better spatial access within areas of higher population density. Several interrelated findings warrant further examination: *1*) better spatial access to FS for neighborhoods with high socioeconomic deprivation and HM remained after stratifying by population density; *2*) compared with a GT approach to directly identify and geocode FS, the exclusive use of PL of FS significantly misrepresented the number, type, and distance of the nearest FS to neighborhoods; and *3*) compared with the use of a population-weighted CBG center as 1 of 2 data points required for measuring distance, the use of the geographic center significantly overstated the neighborhood distance to all types of FS.

TABLE 3 Association between distance to the nearest FS and neighborhood characteristics[1]

	Supermarket		Supermarket/grocery		Convenience		Discount	
Neighborhood characteristics	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Neighborhood deprivation[2]								
MD	5.115	2.817	0.965	2.160	0.013	1.082	2.725	2.078
HD	6.254	4.556	−1.897	3.890	−2.383	1.457	6.148	3.663
Minority composition, %[3]								
MM (15–39)	−7.666[c]	2.773	−6.135[b]	2.193	0.466	1.045	−6.027[b]	2.005
HM (>39)	4.291	3.813	5.255	4.325	2.854	1.980	7.224	3.720
Population density[4]								
Medium (5.4–49.5)	−7.659[b]	2.745	−3.799	2.175	−1.489	0.974	−6.039[b]	2.060
High (>49.5)	−21.078[c]	2.380	−13.005[b]	2.061	−5.719[c]	1.005	−17.618[c]	1.949
HM × HD	−18.558[c]	5.189	−11.947[a]	5.395	−2.187	2.350	−19.006[c]	4.851
HM × MD	−15.718[c]	5.037	−10.551	5.654	−2.078	2.293	−13.305[b]	5.285
R^2	0.519		0.460		0.413		0.539	

[1] Regression results in km, based on simultaneous entry of all variables, are reported as Ordinary Least Square coefficient and robust SE and are corrected with the White-Huber correction. Level of statistical significance: [a] $P < 0.05$; [b] $P < 0.01$; [c] $P < 0.001$.

[2] Reference = LD.

[3] Reference = LM (<15%).

[4] Reference = low population density (<5.4 persons/km^2).

Not only did the most socioeconomically deprived neighborhoods have the best spatial access to all 4 types of FS, but within HD neighborhoods, spatial access was increasingly better for neighborhoods that also had a greater percentage of African American and Hispanic residents (Table 2). This is contrary to published reports of urban areas (14,30). Interestingly, not only were there no HD neighborhoods that had <15% minority residents, but among the 26 neighborhoods with LM, the distance to the nearest FS, regardless of type, was greater in the 12 MD neighborhoods than in the 12 LD neighborhoods. Even after controlling for socioeconomic deprivation, minority composition, and population density, the results of the multivariable regression models extended our knowledge by identifying the coexistence of high socioeconomic deprivation and HM as an independent correlate of better spatial access to the nearest supermarket, grocery store, and discount store. These results persisted in analyses stratified by level of population density.

Compared with previous research that used publicly or commercially available lists of FS (11,14,17,20–24,30), we identified all FS in 6 rural counties using ground truthing and then geocoded all locations on-site using a portable GPS. Evaluation of PL to identify FS in this study area showed that exclusive reliance on PL would misrepresent FS in both directions; that is, PL would include FS that did not exist (18.9%) and omit FS that did exist (35.7%). In fact, 26% of supermarket/grocery stores, 36% of convenience stores, and 20% of discount stores were identified through GT methods only. In addition to affecting the accurate enumeration of the food environment, reliance on PL provided distance measures that significantly misrepresented spatial access for all types of FS when compared with GT methods. To our knowledge, this same level of evaluation of FS identification has not been reported for urban studies in the United States. (12,14,17,30,50).

In addition, despite the ubiquitous use of a geographic centroid as the neighborhood center, population-weighted centroids may be a more accurate depiction of the population center of a rural CBG. A comparison of geographic and population-weighted centroids revealed that the use of a geographic centroid would have significantly overestimated distance and misrepresented potential spatial access when compared with a population-weighted centroid. This is critically important when considering that selection of the method for identification of FS and the choice of centroid (geographic vs. population-weighted) are the 2 points used to construct distance and access measures from a neighborhood to the food environment.

It is especially important to identify the challenges faced by rural residents to the achievement and maintenance of good nutritional health. This study contributes to a greater understanding of part of the challenge: the potential spatial access to different types of FS. The next step will be to better understand the barriers and facilitators for utilization of specific types of FS. Research on the prevention of overweight and obesity has started to recognize that the food choices people make may have more to do with household, neighborhood, and community contexts than with individual psychosocial factors (51–56). In particular, potential spatial access (availability and distance) to supermarkets, which are larger and where consumers usually have greater selection and lower cost for healthful food options than full-line grocery or convenience stores, may provide barriers or facilitators to the actual use of healthy and affordable food resources (9,17,55–57). However, little attention has been paid to the food environment in rural areas, where the prevalence of obesity is higher and where households face considerable geographic and economic challenges (15,58).

Our findings further confirm that rural residents have overall low potential access to FS (50). This is of particular concern, given that greater distance from a supermarket has been associated with the lowest diet quality (23). Spatial inequality experienced by rural families, especially those who are low-income, may further be exacerbated by mobility and time constraints: namely, time spent commuting to work, lack of or limited access to transportation, or not being able to afford the cost of transportation (1,9,50,59).

Limitations to this study also warrant mention. First, the use of administrative-defined areas, such as CBG or census tracts, for a neighborhood may not be consistent with the perceptions of residents (60). Future work is planned to triangulate objective and subjective measures of FS access. Second, measurements of distance to the nearest FS may not be the actual experience of people who choose for a variety of reasons to shop at a store other than the one closest to them. Decisions on where to shop may be influenced by opening hours, standard of service, familial preferences, and established relationships, to name a few (60). Third, data do not capture food purchasing and acquisition patterns, such as who goes shopping, frequency of food shopping, day and time of the typical big shopping trip for food, location, type of items, resources, transportation and route, mobility strategies, and time spent (9,13,61,62). Finally, because we only explored 1 rural region of Texas, we are unable to generalize results beyond this area.

Despite these limitations, this study furthers our knowledge about the rural food environment and the distances households must navigate to purchase needed food. For many residents who lived in neighborhoods that were considered to have better potential access to the food environment, they still had to travel at least 4 km one way to the nearest supermarket or grocery store. For many of these residents, food shopping may be especially challenging; there is no regular public transportation and many households do not have access to a vehicle. All of these factors, along with transportation-related expenses, pose added problems for households in the more isolated rural areas.

Large numbers of an increasingly diverse U.S. population are living in rural areas with a greater burden of disease, increased economic constraints, and greater spatial inequality for access to healthful food (31,32,63). Thus, greater attention must be directed toward the availability and utilization of food resources in rural areas. To foster creative and effective community-based approaches to meeting dietary needs, prospective research that identifies the household, neighborhood, and community barriers and facilitators to healthful food choices needs to be conducted.

Literature Cited

1. Kaufman PR. Rural poor have less access to supermarkets, large grocery stores. Rural Development Perspectives. 1998;13:19–26.
2. Luo W. Using a GIS-based floating catchment method to assess areas with shortage of physicians. Health Place. 2004;10:1–11.
3. Probst JC, Samuels ME, Jespersen KP, Willert K, Swann RS, McDuffie JA. Minorities in rural America: an overview of population characteristics. Report of the South Carolina Rural Health Research Center, University of South Carolina, Columbia (SC); 2002.
4. Liu J, Bennett KJ, Harun N, Zheng X, Probst JC, Pate RR. Overweight and physical inactivity among rural children aged 10–17: a national and state portrait. Report of the South Carolina Rural Health Research Center, University of South Carolina, Columbia (SC); 2007 Oct.
5. Furst T, Connors M, Bisogni CA, Sobal J, Falk LW. Food choice: a conceptual model of the process. Appetite. 1996;26:247–66.
6. Mela DJ. Food choice and intake: the human factor. Proc Nutr Soc. 1999;58:513–21.
7. Connors M, Bisogni C, Sobal J, Devine C. Managing values in personal food systems. Appetite. 2001;36:189–200.
8. Zenk SN, Schulz AJ, Hollis-Neely T, Campbell RT, Holmes N, Watkins G, Nwankwo R, Odoms-Young A. Fruit and vegetable intake in African Americans: income and store characteristics. Am J Prev Med. 2005; 29:1–9.
9. Clifton KJ. Mobility strategies and food shopping for low-income families. J Plann Educ Res. 2004;23:402–13.
10. Popkin BM, Duffey K, Gordon-Larsen P. Environmental influences on food choice, physical activity and energy balance. Physiol Behav. 2005;86:603–13.
11. Block D, Kouba J. A comparison of the availability and affordability of a market basket in two communities in the Chicago area. Public Health Nutr. 2006;9:837–45.
12. Inagami S, Cohen DA, Finch BK, Asch SM. You are where you shop: grocery store locations, weight, and neighborhoods. Am J Prev Med. 2006;31:10–7.
13. Guy CM, David G. Measuring physical access to 'healthy foods' in areas of social deprivation: a case study in Cardiff. Int J Consum Stud. 2004;28:222–34.
14. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML. Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. Am J Public Health. 2005;95:660–7.
15. Blanchard TC, Lyson TA. Retail concentration, food deserts, and food disadvantaged communities in rural America [final report on the Internet]. Southern Rural Development Center; 2002 [cited 2005 Apr 28]. Available from: http://srdc.msstate.edu/focusareas/health/fa/blanchard02_final.pdf.
16. Macintyre S, McKay L, Cummins S, Burns C. Out-of-home food outlets and area deprivation: case study in Glasgow, UK. Int J Behav Nutr Phys Act. 2005;2:16–22.
17. Liese AD, Weis KE, Pluto D. Food store types, availability and cost of foods in a rural environment. J Am Diet Assoc. 2007;107:1916–23.
18. Campbell CC. Food insecurity: a nutritional outcome or a predictor variable. J Nutr. 1991;121:408–15.
19. Morland K, Wing S, Roux AD. The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. Am J Public Health. 2002;92:1761–7.
20. Wang MC, Gonzalez AA, Ritchie LD, Winkleby MA. The neighborhood food environment: sources of historical data on retail food stores. Int J Behav Nutr Phys Act. 2006;3:15.
21. Morland K, Diez Roux AV, Wing S. Supermarkets, other food stores, and obesity. Am J Prev Med. 2006;30:333–9.
22. Blanchard T, Lyson T. Food availability & food deserts in the nonmetropolitan South. Southern Rural Development Center, Mississippi State (MS); 2006 Apr. Policy Report No.: 12.
23. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Prev Med. 2004;39:869–75.
24. Moore LV, Diez Roux AV. Association of neighborhood characteristics with the location and type of food stores. Am J Public Health. 2006;96:325–31.
25. Kravets N, Hadden WC. The accuracy of address coding and the effects of coding errors. Health Place. 2007;13:293–8.
26. Ward MH, Nuckols JR, Giglierano J, Bonner M, Wolter C, Airola M, Mix W, Colt JS, Hartge P. Positional accuracy of two methods of geocoding. Epidemiology. 2005;16:542–7.
27. Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. J Epidemiol Community Health. 2007;61:491–8.
28. Zenk SN, Tarlov E, Sun J. Spatial equity in facilities providing low- or no-fee screening mammography in Chicago neighborhoods. J Urban Health. 2006;83:195–210.
29. Rose D, Richards R. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. Public Health Nutr. 2004;7:1081–8.
30. Morland K, Wing S, Roux AD, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. Am J Prev Med. 2002;22:23–9.
31. Jensen L, McLaughlin DK, Slack T. Rural poverty: the persisting challenge. In Brown DL, Swanson LE, editors. Challenges for rural America in the twenty-first century. University Park, PA: The Pennsylvania University Press; 2003. p. 118–131.
32. Harris RP, Worthen D. African Americans in rural America. In Brown DL, Louis E. Swanson, editors. Challenges for rural America in the twenty-first century. University Park, PA: The Pennsylvania State University Press; 2003. p. 32–42.
33. Strong DA, Del Grosso P, Burwick A, Jethwani V, Ponza M. Rural research needs and data sources for selected human services topics [final report on the Internet]. U.S. Department of Health and Human Services; 2005 Aug [cited 2007 Oct 15]. Available from: http://aspe.hhs.gov/hsp/05/rural-data/vol1.pdf.
34. The Center for Rural Pennsylvania [homepage on the Internet]. Rural/Urban PA [cited 2007 Oct 21]. Available from: http://www.ruralpa.org/rural_urban.html.
35. U.S. Census Bureau [homepage on the Internet]. American Factfinder; 2005 [cited 2005 May 14]. Available from: http://factfinder.census.gov/home/saff/main.html?_lang=en.
36. Brazos Transit District [Web page of services on the Internet]. Bryan, TX [cited 2007 Aug 10]. Available from: http://www.btd.org/.

37. Brazos Valley Council of Governments. "Here to there" coordinated regional public transportation plan. Report. Brazos Valley Region (TX); 2006 Dec.
38. Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. Am J Public Health. 2006;96:2145–53.
39. Voss PR, Long DD, Hammer RB. When census geography doesn't work: using ancillary information to improve the spatial interpolation of demographic data. Center for Demography and Ecology, University of Wisconsin-Madison; 1999 [cited 2007 Aug 4]. Available from: http://209.85.207.104/search?q=cache:c05ZVuTgmk4J:www.ssc.wisc.edu/cde/cdewp/99–26.pdf+Voss+AND+census+geography&hl=en&ct=clnk&cd=2&gl=us.
40. U.S. Census Bureau [homepage on the Internet]. North American Industry Classification System (NAICS); 2004 Dec 29 [cited 2005 Jan 4]. Available from: http://www.census.gov/epcd/www/naics.html.
41. Hanigan I, Hall G, Dear KB. A comparison of methods for calculating population exposure estimates of daily weather for health research. Int J Health Geogr. 2006;5:38.
42. Messer LC, Laraia BA, Kaufman JS, Eyster J, Holzman C, Culhane J, Elo I, Burke JG, O'Campo P. The development of a standardized neighborhood deprivation index. J Urban Health. 2006;83:1041–62.
43. Land KC, McCall PL, Cohen LE. Structural covariates of homicide rates: are there any invariances across time and social space? Am J Sociol. 1990;95:922–63.
44. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. Science. 1997;277:918–24.
45. Matheson FI, Moineddin R, Dunn JR, Creatore MI, Gozdyra P, Glazier RH. Urban neighborhoods, chronic stress, gender and depression. Soc Sci Med. 2006;63:2604–16.
46. Wen M, Hawkley LC, Cacioppo JT. Objective and perceived neighborhood environment, individual SES and psychosocial factors, and self-rated health: an analysis of older adults in Cook County, Illinois. Soc Sci Med. 2006;63:2575–90.
47. Kim J, Mueller CW. Factor analysis: statistical methods and practical issues. Beverly Hills, CA: Sage Publications; 1978.
48. Krieger N, Chen JT, Waterman PD, Soobader M-J, Subramanian S, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter? Am J Epidemiol. 2002;156:471–82.
49. Cuzick JA. Wilcoxon-type test for trend. Stat Med. 1985;4:87–90.
50. Powell LM, Slater S, Mirtcheva D, Bao Y, Chaloupka FJ. Food store availability and neighborhood characteristics in the United States. Prev Med. 2007;44:189–95.
51. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? Science. 2003;299:853–5.
52. Drewnowski A, Rolls BJ. How to modify the food environment. J Nutr. 2005;135:898–9.
53. Glanz K, Sallis JF, Saelens BE, Frank LD. Healthy nutrition environments: concepts and measures. Am J Health Promot. 2005;19:330–3.
54. Booth SL, Sallis JF, Ritenbaugh C, Hill JO, Birch LL, Frank LD, Glanz K, Himmelgreen DA, Mudd M, et al. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. Nutr Rev. 2001;59:S21–39.
55. Drewnowski A. Obesity and the food environment. Am J Prev Med. 2004;27:154–62.
56. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. Prev Med. 1999;29:563–70.
57. White M. Food access and obesity. Obes Rev. 2007;8:99–107.
58. Jackson JE, Doescher MP, Jerant AF, Hart LG. A national study of obesity prevalence and trends by type of rural county. J Rural Health. 2005;21:140–8.
59. Blanchard T, Lyson T. Access to low cost groceries in nonmetropolitan counties: large retailers and the creation of food deserts [report on the Internet]. Southern Rural Development Center; 2002 [cited 2005 May 12]. Available from: http://srdc.msstate.edu/measuring/blanchard.pdf.
60. Ball K, Timperio AF, Crawford DA. Understanding environmental influences on nutrition and physical activity behaviors: where should we look and what should we count? Int J Behav Nutr Phys Act. 2006;3:33.
61. Baranowski T, Missaghian M, Broadfoot A, Watson K, Cullen K, Nicklas T, Fisher J, Baranowski J, O'Donnell S. Fruit and vegetables shopping practices and social support scales. J Nutr Educ Behav. 2006;38:340–51.
62. Kempson K, Keenan DP, Sadani PS, Adler A. Maintaining food sufficiency: coping strategies identified by limited-resource individuals versus nutrition educators. J Nutr Educ Behav. 2003;35:179–88.
63. Morton LW, Blanchard TC. Starved for access: life in rural America's food deserts. Rural Realities. 2007;1:1–10.