The Spatial Distribution of Food Outlet Type and Quality around Schools in Differing Built Environment and Demographic Contexts

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Abstract

Safe and convenient access to healthy foods for all populations is a fundamental transportation and environmental justice concern. Emerging evidence suggests that residents of lower income communities have less access to healthy food choices than those in higher income areas. Most studies to date rely on an assumed level of food quality generalized across different types of food outlets (e.g., grocery versus convenience stores) mapped in space. The current study includes a detailed audit of food quality offered in 302 food establishments in four communities in the Atlanta Region and compares proximity to these outlets in differing urban and demographic settings. The analyses focus on a middle and elementary school in each community and compare the spatial relationships between schools and sit-down and fast food restaurants and between grocery and convenience stores. Road network distances from school sites to each food outlet were calculated in a geographic information system. Results suggest that food quality varies across neighborhoods by income, but not by walkability. Results also suggest the potential for food quality to vary differentially with distance from schools in higher versus lower income communities. Walking or biking to get food is difficult in auto-oriented environments which has important implications on sustainability. Youth, elderly, and other populations which do not drive are more reliant on the food choices offered in their immediate environments, such as in schools or assisted living facilities. Methods employed can be expanded to examine associations between food outlet quality, urban form, travel and activity patterns, dietary behavior, and health outcomes.

Introduction

Emerging research suggests the relative ease of access to healthy versus unhealthy foods may be linked with individuals' dietary behavior (Glanz, Sallis et al. 2005). While not yet proven, it would stand to reason that the nutritional quality of foods that are both proximate in space and financially attainable (Drewnowski and Specter 2004) impact body mass index and other predictors of population health. While not commonly studied, the ability to access food is a major component of non-work related travel and is a primary function of urban transportation systems. The level of accessibility to healthy foods is an important quality of life indicator. Potential systematic disparities in access across income levels can constitute benefits and burdens for specific groups and is a relevant environmental justice concern. Moreover, increased proximity to healthy food choices from schools or where people live and work can offset vehicle use, increase transportation-related physical activity, and promote a more sustainable transportation system.

The purpose of this paper is to describe and apply a geographic information system (GIS) based methodology to measure the spatial variation in food quality accessibility across levels of neighborhood walkability and income. This methodology is used to measure the proximity of schools to food outlets by type and by nutritional value. An audit tool was developed and applied to assess food quality in four types of food outlets including fast food, restaurant, convenience, and grocery stores (Glanz et al 2006).

This paper is part of the Nutritional Environment Measures Study (NEMS --http://www.sph.emory.edu/NEMS) which has the purpose of establishing a definition of community food environments and to establish a system of measuring the quality of those environments. Since environmental factors affect behavior, it is difficult to establish and maintain healthy behaviors when environmental factors create substantial barriers to attempted behavior changes. Travel survey data show that most trips are for non-work purposes and many of these non-work trips involve food. Shorter home based non-work trips are more likely to be viable on foot or bike and provide important opportunities to promote active and sustainable transportation solutions.

A growing body of evidence suggests important relationships may exist between food outlet proximity and health-related outcomes (e.g., body mass index). Evidence further suggests the potential for disparities to exist between the quality of food closest to people of different economic strata. In this initial pilot study, we examined food environments around elementary and middle schools in response to the emerging epidemic of childhood obesity and in order to further the search for promising "public health" or population oriented approaches to address this problem. As students get older, they are increasingly likely to purchase foods that they pay for inside of or nearby to their schools and residences (Neumark-Sztainer et al 2005; Craypo et al 2002). Middle schools often have "open campus" policies where students can leave the school grounds for lunch or to buy food at nearby stores and restaurants. High school catchment areas were thought to yield neighborhoods too large for our assessment purposes.

Past research has shown a distinct link between proximity of health care resources and frequency of use of those resources. Many transportation planning studies employ a "gravity model" which predicts that the likelihood an individual will visit a destination declines exponentially with distance (Zipf 1949). This concept is known as distance decay and has been recently employed within physical activity research to predict park and open space use (Giles-Corti 2005). Thus, there is reason to suspect access to food sources could have similar relations to food purchasing and dietary intake.

Recent studies have shown that access to specific types of food establishments can have a significant impact on diet and health. Laraia et al. found pregnant women closer to supermarkets had a higher diet quality index (Laraia, Siega-Riz et al. 2004). Distance was measured as a Euclidean (straight-line) distance between pregnant women's homes and food outlets. Austin et al. found that fast food restaurants cluster around schools. Fast food restaurants were geocoded to their street address and a bivariate K function analysis was used to determine the presence of spatial clustering of fast food restaurants near schools (Austin, Melly et al. 2005).

Burdette and Whitaker used a GIS-based approach to quantify the relationship between fast food restaurants, crime rate, presence of playgrounds, and childhood obesity in a low income population (Burdette and Whitaker 2004). Proximity was measured using a child's home address and calculating the Euclidean distance between their home and fast food restaurants, as well as playgrounds. Findings suggested that proximity to these resources was not a factor in childhood obesity.

GIS-based approaches have been used to assess a variety of "influencers" of behavior and health related outcomes. For example, studies have assessed the impact of alcohol outlet density on violence in Brazil (Laranjeira 2002) and in Austin, TX (Zhu 2004). GIS analysis of grocery store locations has also been conducted in a number of cities, revealing a consistent association between proximity or presence of grocery stores and more healthful diets (Morland, Wing et al. 2002; Rose and Richards 2004; Zenk, Schulz et al. 2005). This finding is arguably a function of the lack of grocery stores in several of the most impoverished urban core areas of the United States.

Methods

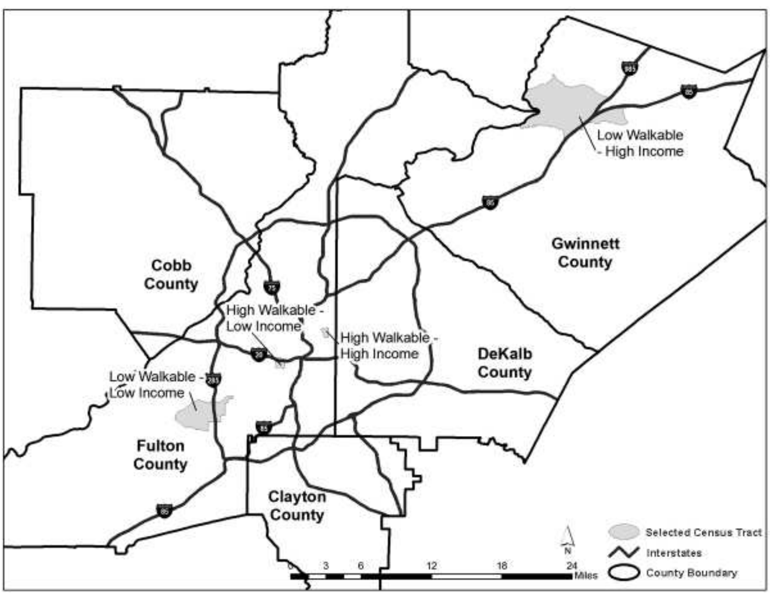
Study Sites

Elementary and middle schools in four neighborhoods in the Atlanta Region were selected for the study, as shown in Figure 1. The neighborhood selection process supports comparisons of food outlet accessibility around schools with high and low levels of walkability and income. The neighborhood selection process included at least one middle school in each neighborhood and one or more elementary school.

Walkability was measured based on the degree to which residential and commercial uses are intermixed, residential density, and presence of an interconnected road network versus a cul-de-sac road layout (Frank et al. 2005; Frank et al 2006). High walkability was defined as having several land uses intermixed and higher levels of residential density and street connectivity. Each neighborhood defined as a census tract was given a "walkability" score based on the measures defined above. An area with a high measure of walkability would imply that there is a road network which lends itself to pedestrian use, and that pedestrians can access different types of land uses (stores, schools, homes, etc.) on foot.

One neighborhood was selected to represent each of four categories: high walkable/high income, high walkable/low income, low walkable/high income, and low walkable/low income. Measures of walkability and income were developed at the census tract scale. Each neighborhood defined census tract was assigned a one-mile buffer delineating the study area. All neighborhoods and the corresponding census tracts contained a middle school and at least one elementary school.

Figure 1. Study Area



Measurement Procedures

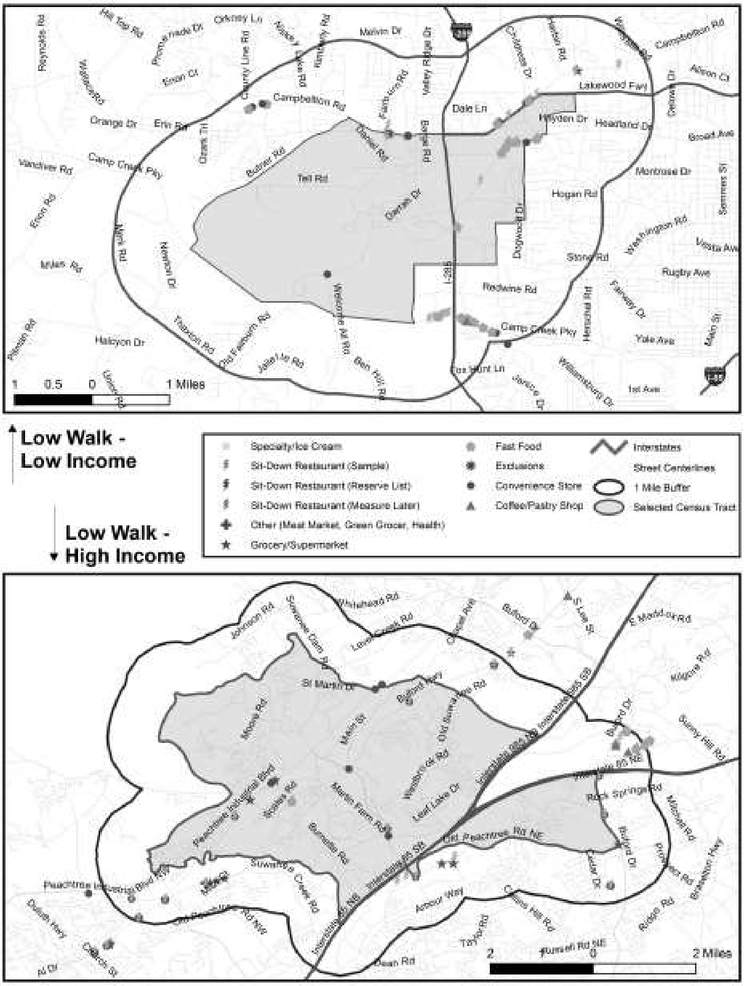
Food outlets were enumerated and categorized in each of the four study areas. The street addresses of food outlets were collected using county Board of Health License Lists, as well as Electronic Yellow Page Directories. These food outlets were categorized according to type – convenience vs. grocery store and sit-down vs. fast food restaurant. A total of 85 stores (Glanz et al. 2006) and 217 restaurants (Saelens et al. 2006) were enumerated in the four study neighborhoods. A rigorous process was employed whereby observational measures for each type of food outlet were developed and their validity and reliability was established. Once trained on the use of a standardized protocol and set of forms, raters evaluated food outlets in each of the four communities shown in Figure 2 (less walkable) and Figure 3 (more walkable), which convey the locations of the food establishments by type and the schools in each of the four neighborhoods.

Through this process, a measure of nutrition environment quality (NEMS score) was developed for retail stores (convenience and grocery) by evaluating the availability of the following: milk, fruit, vegetables, ground beef, hot dogs, frozen dinners, baked goods, beverages (soda/juice), whole grain bread, and baked chips. This evaluation process measures availability of healthful choices, prices, and quality. Raters evaluated these factors among the products identified above through systematic observations during site visits. A scoring system was developed, and a higher NEMS score denotes more healthy food choices, better or equal price for healthy choices, and high quality (Glanz et al. 2006). The NEMS rating system is the focus of a detailed paper (Glanz et al. 2006) on the NEMS food store evaluation protocol.

A similar evaluative system was developed for sit-down and fast food restaurants. The factors related to a restaurant's nutrition environment score include: healthy main dish choices (low-fat, low-calorie, healthy main dish options); availability of fruit, vegetable, whole grain bread, and baked chips; beverages; and children's menus. Included in the restaurant's score were also variables that might act as a facilitator or a barrier to healthy eating, namely pricing, signage, and promotions. Raters conducted evaluation of restaurants through site visits, examination of take-away menus, manager interviews, and internet menu analysis (Saelens et al. 2006).

In order to ensure consistency and reliability of findings in each location, two raters visited each location independently on the same day. Consistency in types of foods available was verified by making two visits to each location, the second visit approximately one month after the first. Test-retest and inter-observer agreement reliabilities were above 0.80 for both stores and restaurants, and the test-retest reliabilities were mostly above 0.70 and are reported elsewhere (Glanz et al. 2006; Saelens et al. 2006). NEMS scores

Figure 2. Low Walk Communities by Income

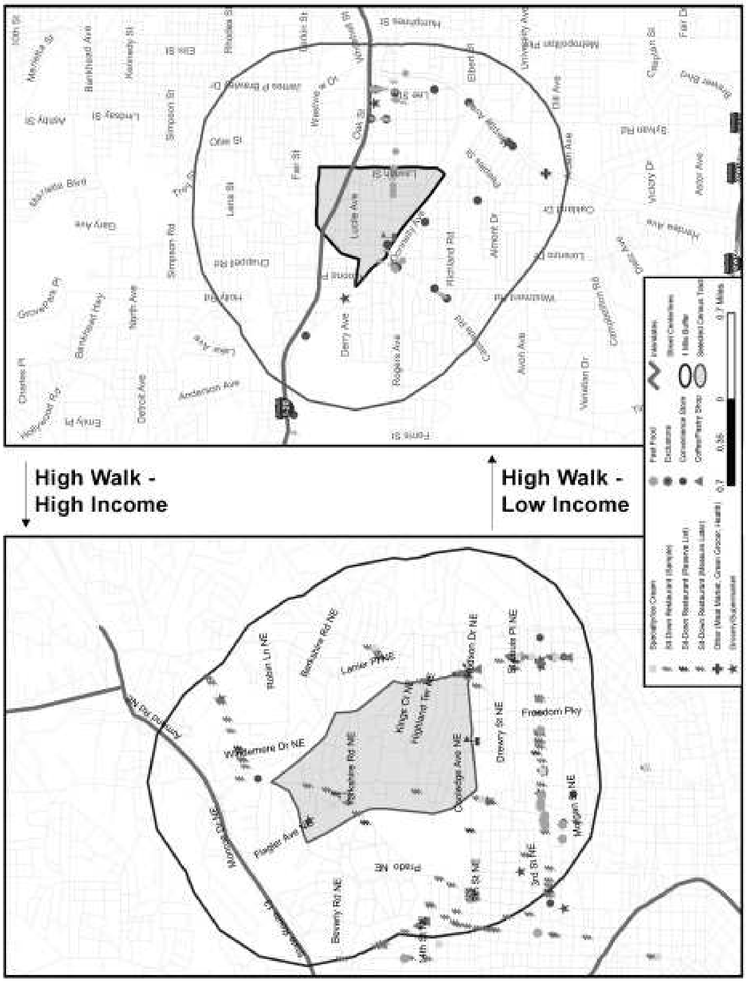


were attached as attributes to the geocoded location with final scores in the current study ranging from 2.5 to 32 for stores (on a scale of 0 to 50), and –10 to 36 for restaurants (on a scale of –27 to 60).

Results

Each food outlet was matched to its street address, using GIS (ArcView 9.0 ESRI). Geocoding is a process by which an address is matched to the corresponding street center line in a digital file. Locations of middle and elementary schools were recorded, using County School Board data. The

Figure 3. High Walk Communities by Income



302 food outlets (grocery and convenience stores, sit-down and fast-food restaurants) that were evaluated, and whose addresses were successfully geocoded, are shown in Table 1.

Distance from each food outlet to schools within each neighborhood was calculated using GIS. A road network distance was measured to approximate real world accessibility of food outlets to schools. A relative mean road network distance between schools and outlets was calculated in order to determine if more or less healthy food choices are located closer to schools by food outlet type within each community. Therefore numbers less than 1.0 represent where distances were shorter to convenience and fast food

Table 1. Frequency of Food Sites by Type and Community

Walkability/Income	Type	N (food sites)	Total
Low/High	Grocery	6	
	Convenience store	20	
	Sit-down restaurant	43	
	Fast-food restaurant	28	97
Low/Low	Grocery	2	
	Convenience store	14	
	Sit-down restaurant	17	
	Fast-food restaurant	30	63
High/High	Grocery	9	
	Convenience store	9	
	Sit-down restaurant	40	
	Fast-food restaurant	22	80
High/Low	Grocery	7	
	Convenience store	18	
	Sit-down restaurant	15	
	Fast-food restaurant	22	62

outlets than to sit-down restaurants and grocery stores. This measure was calculated for distance to elementary schools as well as to middle schools to determine if patterns of location were different for each type of school, as shown in Table 2.

Outlets in the high walkability study areas were split into two groups — those less than 0.75 miles (road network distance) from a school, and those farther than 0.75 miles. This distance was determined to be one that can be walked relatively easily for a child, as well as one in which at least one food outlet was located for each of the two high walkability neighborhoods. Once split into these distance-based groups, mean NEMS quality scores were determined by type of food outlet for each community, by school type, as shown in Table 3. The same process was repeated for the low-walkability communities, although the distance used in this part of the analysis was a less walkable three miles given that the few food outlets were so dispersed, as shown in Table 4.

To determine the best method to detect spatial clustering of food outlets near schools, a second type of analysis was done, using concentric buffers surrounding each school. This pilot analysis was conducted for middle schools only. Six different road network based buffers were created around each school. Study areas with more connectivity in the road network (grid-like, fewer cul-de-sacs) are expected to have buffers with larger areas than

Table 2. Relative Mean Road-Network Distance from Middle and Elementary Schools to Food Outlet by Community (All Food Outlets)

Food Outlet Type	Low Walk High Income	Low Walk Low Income	High Walk High Income	High Walk Low Income
Middle Schools				
Convenience/ grocery store	90.5%	80.0%	100.9%	86.0%
Fast-food/sit-down restaurant	107.0%	92.4%	99.7%	94.8%
Elementary Schools				
Convenience/ grocery store	99.7%	122%	105.2%	92.1%
Fast-food/sit-down restaurant	97.2%	98.1%	131.9%	97.2%

100% means these places are equidistant, <100% means the numerator food outlet type is closer than the denominator food outlet type.

those with fewer interconnected streets. Buffer sizes were determined with pedestrian travel in mind. The smallest buffer size was 0.25 miles, and the largest was 1.25 miles. The intervening buffers increased in 0.25 mile increments. Each larger concentric buffer included all areas in the previous buffers. The number of food outlets within each buffer was tabulated, by type, for middle schools, as shown in Table 5. Mean NEMS scores for each outlet type were also determined within each concentric buffer and for the entire study area around each school.

A third method of analysis was employed, using GIS software to detect spatial clustering of food outlets. Using ArcView, a Moran's I statistic was calculated, in a similar fashion as that used in the Zenk Detroit supermarkets study (Zenk, Schulz et al. 2005). The Moran's I statistic detects spatial clustering using location and attribute values for each feature. The attribute used for the food locations was the road network distance to schools, and the feature location was place on the road network. Moran's I in this case describes the degree of clustering of food outlet locations by considering those features with similar weights to be like features. Clustering for like features is determined by their road network distance from one another. Moran's I statistics was only calculated for a subset of the database — those

Table 3. Mean NEMS Scores, High Walk Communities — Closer Than and Greater Than 0.75 Miles from Middle and Elementary Schools

Community	Type	Distance (road network, miles)	MIDDLE		ELEMENTARY *	
			N	Mean NEMS Score	N*	Mean NEMS Score*
High Walk – High Income	Grocery	< 0.75	2	26.50	0	
		0.75+	7	24.86	9	25.22
	Convenience Store	< 0.75	1	14.00	0	
		0.75+	8	6.63	9	7.44
	Sit-down Restaurant	< 0.75	13	3.31	1	-3
		0.75+	27	5.44	39	4.95
	Fast Food Restaurant	< 0.75	1	6.00	0	
		0.75+	21	6.38	22	6.36
High Walk – Low Income	Grocery	< 0.75	2	24.00	2	24
		0.75+	5	17.20	5	17.2
	Convenience Store	< 0.75	5	4.40	6	4.67
		0.75+	13	5.08	12	5
	Sit-down Restaurant	< 0.75	5	1.20	1	-3
		0.75+	10	5.50	14	4.57
	Fast Food Restaurant	< 0.75	10	7.10	5	-3.8
		0.75+	12	1.00	17	6

Note: * Food outlets were grouped into distance categories based on their relationship to all elementary schools. For example, an outlet is placed in the 0.75+ mile category only if it is not closer than that to any school. If an outlet is within 0.75 miles of one (or more) schools it is placed in the < 0.75 mile category.

locations in the high walkability, high income quadrant, as part of the pilot study to determine its utility for use in future analysis. Statistically significant results were found for the clustering of sit-down restaurants around middle schools, with a Moran's Index of 0.494, and an expected Index of –0.026, and a Z-score of 5.719.

Analysis

The findings describe the relative proximity between schools and different types of food outlets and nutritional quality in our four different community environments. The results are exploratory given there are only four different communities being evaluated, and the emphasis is on describing the application of the measures and analytic methods. However, some interesting patterns emerged in terms of distances from schools to different types of food outlets and their food quality.

Table 4. Mean NEMS Scores, Low Walk Communities—Closer Than and Greater Than 3 miles from Middle and Elementary Schools

Community	Type	Distance (road network, miles)	MIDDLE		ELEMENTARY	
			N	Mean NEMS Score	N	Mean NEMS Score
Low Walk – High Income	Grocery	< 3	0		4	23.5
		3+	6	24.86	2	27.0
	Convenience Store	< 3	4	6.75	12	7.17
		3+	16	6.81	8	6.25
	Sit-down Restaurant	< 3	3	13.67	14	9.53
		3+	40	10.05	29	11.24
	Fast Food Restaurant	< 3	0		9	4.0
		3+	28	9.46	19	8.21
Low Walk – Low Income	Grocery	< 3	0		2	16.5
		3+	2	16.50	0	
	Convenience Store	< 3	6	6.33	14	4.71
		3+	8	3.50	0	
	Sit-down Restaurant	< 3	3	5.00	17	9.29
		3+	14	10.21	0	
	Fast Food Restaurant	< 3	6	-2.00	30	3.3
		3+	24	4.63	0	

For Middle Schools — Fast food restaurants were closer, on average than sit-down ones in all but the low walk/high income community and convenience stores were closer than grocery stores in all but the high walk/ high income community. The distance to convenience stores was 20 percent less than to grocery stores in the low walk/low income community.

For Elementary Schools — Fast food restaurants were closer, on average than sit-down restaurants in all but the high walk/high income community where distances to sit down restaurants was 32 percent less than to fast food. Convenience stores, on average, were nearly the same distance as grocery stores in the low walk/high income and closer in both the high and low walk/low income communities. While exploratory in nature, these results suggest the possibility that neighborhood type and demographics may be related with food outlet siting.

The spatial clustering of food outlets was further examined based on the actual quality of the food choices estimated from the Nutrition Environment Measurement Study (NEMS) quality score. A distance of 0.75 miles and 3.0 miles was used in the high and low walkable communities respectively to compare differences in overall food outlet quality (mean NEMS scores) between what is closest and furthest from school sites. Overall findings

Table 5. Frequency of Food Outlets (by Type and Community) Grouped by Distance from Middle Schools

Community (Walkability/ Income)	Type	Distance from School (road-network, miles)					
		<0.25	<0.5	<0.75	<1.0	<1.25	Study Area*
		N (# of food outlets)					
Low Walk / High Income	Grocery	0	0	0	0	0	6
	Convenience Store	0	0	0	0	1	20
	Sit Down Restaurant	0	0	0	0	1	43
	Fast Food Restaurant	0	0	0	0	0	28
Low Walk / Low Income	Grocery	0	0	0	0	0	2
	Convenience Store	0	0	0	0	2	14
	Sit Down Restaurant	0	0	0	0	0	17
	Fast Food Restaurant	0	0	0	0	1	30
High Walk / High Income	Grocery	0	1	1	3	6	9
	Convenience Store	0	1	1	1	5	9
	Sit Down Restaurant	0	3	12	19	22	40
	Fast Food Restaurant	0	0	0	11	14	22
High Walk / Low Income	Grocery	1	1	2	2	4	7
	Convenience Store	1	2	5	10	16	18
	Sit Down Restaurant	3	5	5	10	11	15
	Fast Food Restaurant	2	7	10	13	17	22

* Study area is the census tract plus a one-mile buffer around it.

suggest higher NEMS scores in the higher income communities. In both of our high walkability communities grocery stores closer (within 0.75 miles) to middle schools had higher NEMS scores, while closer sit-down restaurants had lower NEMS scores than sit-down restaurants farther away, but still in the same neighborhood. In the high walk/high income community, convenience stores closer to the middle schools had higher NEMS scores. There were no grocery stores or fast food restaurants within 0.75 miles of an elementary school in the high walk/high income community. In the high walk/low income quadrant, grocery stores had higher mean NEMS scores within close proximity to schools, while convenience stores showed little NEMS score difference based on distance. Both fast food and sit-down restaurants were shown to have higher NEMS scores when located farther from a school.

A 3-mile comparison threshold was used in our low walk communities where facilities were more spread out. For the middle school in the low walk/high income area there was little difference in NEMS score for convenience stores based on distance. Sit-down restaurants were shown to have higher NEMS scores in the under-3-mile group. No fast food restaurants or grocery stores were within 3 miles of a middle school in this low walkability area. In the low walk/low income community both types of restaurants had lower NEMS scores in the under 3-mile group. Doing the same calculations for elementary schools in the low walk/high income area showed that NEMS quality scores increased for all food outlet types, other than convenience stores, as distance from a school increased. No food outlets were located over 3 miles from an elementary school in the low walk/low income community.

The concentric buffer analysis presented in Table 5 conveys the observation that low-walkability communities did not have any food outlets within 1.25 miles of the selected middle school. The high walkability communities had 34 food outlets within a mile from the middle school and the middle school in the high walk/low income community had seven food establishments and all four types within a quarter mile. In this high walk/low income community, grocery stores had declining mean NEMS scores with each larger buffer away from the school. The other food outlet types did not show such a consistent trend with distance from school in this community. The high walk/high income area had three of the four types of food outlets within the 1-mile buffer, but showed no pattern or trend in NEMS scores based on distance from the middle school.

Very few food outlets at all existed within 1.5 miles of the low walk communities. Food choices provided in schools in similar low-walkability communities would logically have the potential for a greater impact on diet than students located in areas with alternative food choices.

Subsequent analyses were conducted to demonstrate the ability to develop food quality (mean NEMS scores) for the quarter mile buffer from each middle school. The mean NEMS scores for the full study area or largest buffer covers a considerable amount of each community's food environment. Results suggest more differences in food quality available in the communities across income level and fewer differences across walkability level (Glanz et al. 2006; Saelens et al. 2006).

Discussion

A new and innovative set of methods to define and quantify a "community food environment" in a geographic information system is presented. These methods can be applied in larger, more robust studies of community environments to determine systematic spatial relationships between food access quality and neighborhood characteristics. This pilot assessment focused on the food environments around schools, but similar assessments could be made of other settings and other at-risk populations, including older adults in assisted living facilities and lower income or racial/ethnic minority populations, who are more likely to be obese. The research design presented provides the opportunity to assess interactions between neighborhood design and income as they relate to the quality of food access, which is an important environmental justice concern.

Analyses are presented based on the spatial distribution of food outlet type and food outlet quality around elementary and middle schools. Comparisons between food access by outlet type and quality within and between communities appeared to vary based on walkability and income. Considerable variation in distance from schools to food outlets emerged across the four different community types. Comparative assessments were made suggesting the possibility of some disparities in food outlet location and food outlet quality across income and walkability.

It is important to incorporate a uniform distance measure between communities of the same type, but finding a measure that will produce comparable results for all communities of a given type was a major challenge. This issue raises questions not only of appropriate distance, but of also why the presence of food outlets within a specified distance might vary from community to community. The variability might be attributed to socio-economic factors such as income level, as was found in Reidpath's study of fast-food density and socio-economic status (Reidpath, Burns et al. 2002). Results presented here suggest that accessibility to any food outlet type on foot in lower walkability areas is difficult from schools, leaving youth to be more dependent on food choices available within schools, at home, or through being driven to other food outlets. Increased proximity to healthy food choices near to schools could promote active transportation while enabling healthier diets and further reduce auto dependence in older youth.

Low-income urban neighborhoods often have a greater number of convenience stores and a lower number of grocery stores than high-income suburban neighborhoods, influencing not only residents' access to healthy food choices, but also the cost of food (Curtis 1995). The variation and richness of food environments reflects largely the interface between zoning designation and income. Zoning influences the ability for commercial uses to be intermixed with residential and school environments, and income establishes the market for such uses to co-locate. The walkability measure presented here captures elements of "regulatory permission" to locate food establishments whereas income impacts business opportunity, profitability, and attractiveness. Lot size and parking requirements also determine the location of activities in space.

There are several limitations with the current study. Foremost, it is a pilot study and does not offer any ability to explain systematic associations between community design, income, and food access quality. Variations in urban form in the study make it difficult to assess which factors are most influential in explaining access to food environments, including distances and variations in income and walkability, which are all highly interactive.

However, as a pilot study, the NEMS project has been successful in developing criteria and methods for rating quality of food outlets and in examining several methods of evaluating the spatial distribution of food outlets and their quality. The methods reported here can be used to evaluate disparities in access to healthful foods and to document the relation of access to healthful foods to dietary patterns and health outcomes. Understanding the health impact of food environments can inform changes in public policies and business practices that are needed to help people improve their eating habits to reduce the risk of diseases. It is well understood that non-work trips, such as dining out, grocery shopping, and entertainment, comprise the majority of trips taken in the U.S. each day. Proximity to food outlets and the presence and quality of pedestrian connections will influence whether people will walk, bike, drive, or take public transportation for this major travel purpose. A sustainable urban transportation system can only be achieved where it is possible to access basic daily needs, like food, in ways that promote healthy people and healthy places.

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