Health & Place 18 (2012) 854–860

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Neighbourhood food environments and obesity in southeast Louisiana☆,☆☆

Paul L. Hutchinson [a,*], J. Nicholas Bodor [b], Chris M. Swalm [c], Janet C. Rice [d], Donald Rose [b]

[a] Department of Global Health Systems and Development, Tulane University, School of Public Health and Tropical Medicine, 1440 Canal Street, Suite 2200-TB46, New Orleans, LA 70112, USA
[b] Department of Global Community Health and Behavioral Sciences, Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, Suite 2301, New Orleans, LA 70112, USA
[c] Academic Information Systems, Tulane University, School of Public Health and Tropical Medicine, 1440 Canal Street, TMC SL-18, New Orleans, LA 70112, USA
[d] Department of Biostatistics and Bioinformatics, Tulane University School of Public Health and Tropical Medicine, 1440 Canal Street, TMC SL-18, New Orleans, LA 70112, USA

ARTICLE INFO

Article history:
Received 7 October 2011
Received in revised form
17 February 2012
Accepted 9 March 2012
Available online 18 March 2012

Keywords:
Food environment
Healthy food access
Obesity
Overweight
In-store survey

ABSTRACT

Supermarkets might influence food choices, and more distal outcomes like obesity, by increasing the availability of healthy foods. However, recent evidence about their effects is ambiguous, perhaps because supermarkets also increase the availability of unhealthy options. We develop an alternative measure of food environment quality that characterizes urban neighborhoods by the relative amounts of healthy (e.g. fruits and vegetables) to unhealthy foods (e.g. energy-dense snacks). Using data from 307 food stores and 1243 telephone interviews with residents in urban southeastern Louisiana, we estimate a multilevel multinomial logistic model for overweight status. We find that higher quality food environments – but not food store types – decrease the risk of obesity (*RR* 0.474, 95% *CI* 0.269–0.835) and overweight (*RR* 0.532, 95% *CI* 0.312–0.907). The findings suggest a need to move beyond a sole consideration of food store types to a more nuanced view of the food environment when planning for change.

1. Introduction

A number of studies have examined the relationship between obesity and neighborhood food environments, with the majority of these studies focusing principally on how types of stores, particularly supermarkets, influence residents' food consumption patterns and subsequent risk of obesity. Much of this work has suggested that greater supermarket access enhances the dietary quality of nearby consumers and reduces obesity risk (Inagami et al., 2006; Morland et al., 2006; Lopez, 2007; Powell et al., 2007; Morland and Evenson, 2009; Chen et al., 2010), but recent evidence in support of this is less convincing and suggests a more nuanced relationship (Pearce et al., 2008; Boone-Heinonen et al., 2011; Leung et al., 2011). Rose and Richards (2004), for example, have highlighted issues related to safety and walkability, work schedules, and other time factors that can affect the likelihood that residents utilize local supermarkets. Still other researchers have focused on how perceived quality differences in supermarkets serving white and black neighborhoods can affect consumer behaviors (Kumar et al., 2010). Greater access to smaller food retailers, on the other hand, has been shown to have the opposite effect on obesity risk (Morland et al., 2006; Zenk et al., 2009; Bodor et al., 2010), particularly among certain sub-populations such as low-income groups and Latinos.

While it has been hypothesized that the greater availability of healthy food options within supermarkets and the large amount of energy-dense foods in small stores may account for these findings, supermarkets are also known to carry large amounts of unhealthy foods, and, contrary to prevailing wisdom, some small retailers do carry limited amounts of healthy foods, like fresh fruits and vegetables (Block and Kouba, 2006; Connell et al., 2007; Farley et al., 2009). Hence, research that uses store types as a proxy for food environment quality may not accurately measure access to healthy and unhealthy food options.

A multi-dimensional approach to assessing food environments that integrates information on in-store food availability with the geo-mapping of stores may therefore provide an improved depiction of those environments (Morland et al., 2002; Rose et al., 2010; Walker et al., 2010; Gordon et al., 2011). Such research has found associations between the availability of certain foods within stores with the

Abbreviations: Used: RR, relative risk; BMI, Body Mass Index; CI, confidence interval; K, kilometer

☆This work was funded by the Centers for Disease Control and Prevention through the Prevention Research Centers Program (Cooperative Agreement #5U48DP001948-02), including the Nutrition and Obesity Policy, Research and Evaluation Network (NOPREN); the National Cancer Institute (#R21CA121167); and the National Research Initiative of the U.S. Department of Agriculture's National Institute for Food and Agriculture (#2006–55215-16711). The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the CDC, NCI, or USDA.
☆☆Author disclosure: Conflict of interest: none declared.
* Correspondending author. Tel.: +504 988 6078, fax: +504 988 3653.
E-mail address: phutchin@tulane.edu (P.L. Hutchinson).

1353-8292/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.healthplace.2012.03.006

intake of these foods by local residents (Cheadle et al., 1991; Edmonds et al., 2001; Bodor et al., 2008). Work in Baltimore, for example, found that the lower availability of healthy foods in nearby stores was associated with poorer quality diets (Franco et al., 2009). A study in southeastern Louisiana found that greater neighborhood shelf-space for energy-dense snack foods was positively associated with local residents' BMI (Rose et al., 2009).

Building upon the small number of studies that use a multi-dimensional approach, this study uses food environment measures involving information on geo-mapped stores and in-store data to address an unexamined issue of whether the relative availability of healthy to unhealthy food options influences obesity risk. This study makes use of a unique data set which combines information on access to different types of retail food outlets with information on in-store quantities of healthy foods (e.g. fruits and vegetables) and energy-dense snack foods (e.g. chips, candies, sodas, and pastries). Following the lead of other researchers (Rabe-Hesketh and Skrondal, 2005; Morland et al., 2006; Black et al., 2010; Bodor et al., 2010), multilevel modeling was used to calculate the associations between individual, household and neighborhood food environment characteristics and obesity prevalence. This approach allows us to assess the relative contributions of multiple aspects of neighborhood food supply environments – not just store types but actual measures of in-store food contents and geospatial dispersion – on levels of obesity in urban populations.

2. Methods

2.1. Data

Data for this study originate from urban tracts in southeastern Louisiana, defined as those that had a population density of at least 2000 people per square mile. This included the cities of New Orleans, Baton Rouge, and Lafayette. A total of 114 census tracts were randomly chosen from 379 urban census tracts in the 10-county area (Rose et al., 2009). Data collection began in October 2004 and was ceased due to Hurricane Katrina in August 2005, at which time data collection had been completed in 103 of the sampled tracts.

The study consisted of three data collection components: (1) a mapping of all retail outlets that sold food in the study tracts and in neighboring areas, (2) in-store surveys from a complete census of stores in the study tracts, and (3) a telephone survey of tract residents.

2.1.1. Mapping of retail outlets

To identify retail food outlets in the sampled tracts, a list of all such outlets was obtained from the Louisiana Department of Alcohol and Tobacco Control. All stores in the sampled tracts were mapped and enumerated by pairs of observers who drove along all streets and recorded the address and type of each store. The total number of stores identified in this manner was 307. This information was then geo-coded using ArcGIS 9.2.

Because residents might make purchases at stores in census tracts adjacent to where they lived, information (e.g. addresses, annual store sales) was also collected from all stores ($N=2614$) in the broader 10-county area using the Louisiana Office of Public Health's retail food permitting database. As described below, information on the in-store contents of these stores was imputed from data on the 307 stores that were directly observed.

Grocery stores with sales greater than $5 million/year were classified as supermarkets, and all other stores were classified as small stores. Complete details of the store enumeration procedure have been reported previously (Rose et al., 2009).

2.1.2. In-store survey

Each sampled store in the 103 study tracts was visited by two enumerators, who conducted an in-store survey focusing on the type of store, its total floor space, the number of registers, and food availability. Each store was notified in writing prior to data collection. Of the 307 stores, 218 (71%) consented to observation and measurement of in-store contents. The remaining 89 stores (29%) refused to participate and an abbreviated data collection form was used. Information on shelf space allocated to specific food types was then imputed from the completed stores based on store type, size, number of registers, and location.

Measurement of the linear length of display allotted to groups of foods was performed using a rolling tape measure (Measure Master, Rolotape Corporation). Separate measures were taken for fresh fruits, fresh vegetables, as well as for canned and frozen versions of these foods. Throughout the paper we refer to these as "healthy foods". The length of display shelf space allotted to four categories of energy-dense snack foods (candies; salty snacks, such as potato chips; cookies and pastries; and carbonated beverages) was also assessed. For the sake of brevity, we refer to these throughout the paper as "junk foods". Training of the enumerators occurred in actual stores in a non-sampled tract. Inter-rater reliability measures were high, with values of greater than 0.95 for shelf-length measures on fruits and vegetables.

2.1.3. Telephone survey

The telephone survey was conducted of individuals in the sampled census tracts (Clearwater Research, 2005). For each tract, telephone numbers for 150 households were randomly selected from listed numbers that had been geo-coded and found to fall within the census tract boundaries. If a census tract was not found to have 150 listed household numbers, all listed households were included in the sample.

To minimize refusals, several measures were undertaken to inform potential respondents about the research project and to educate them on the purpose and importance of the study. Advance letters, which explained the data collection and encouraged respondents to participate, were sent to all unique addresses in the household sample. Other measures included incentive checks, toll-free numbers, and answering machine messages (Clearwater Research, 2005)

Within sampled households, interviewers randomly selected an interviewee between the ages of 18 and 65 years. Interviews were conducted by professional interviewers at Clearwater Research Inc. using a Computer-Assisted Telephone Interview system. The refusal rate for the full Louisiana sample was 37.0%.

The questionnaire collected information from 1302 respondents on the household's address, basic demographics on the respondent, including car ownership, and height and weight of the respondent, though missing values on certain variables, particularly height and weight, limited the final sample to 1243 respondents. Additional details regarding the telephone survey have been published previously (Clearwater Research, 2005).

2.2. Individual-level variables measures

2.2.1. Dependent variable

The primary outcome for this analysis was a categorical variable indicating whether or not a person was classified as "normal," "overweight" or "obese" as measured by body mass index (BMI). Height and weight were self-reported by respondents, who provided their weight in pounds and their height in feet and inches. This information was converted into BMI, specifically, weight, in kilograms, divided by height, in meters, squared. Individuals with a BMI of 25 or more, but less than 30, were classified as "overweight," while those with a BMI equal to or exceeding 30 were classified as "obese." Only 19 individuals (1.5%) had a BMI of less than 18, which is considered "underweight." For analytical purposes, this category was collapsed into the "normal" weight category.

Among the complete sample of 1,243 telephone survey respondents, 491 (39.5%) were classified as "normal" BMI, 409 (32.9%) were classified as "overweight," and 343 (27.6%) were classified as "obese."

2.2.2. Independent variables

Individual characteristics of respondents included age (18–30 years, 30–50 years, and 50+ years), gender, race (White Caucasian, Latino, African American or other), level of education (high school or less, some college, college graduate), and days of exercise per week. We also controlled for household socioeconomic status with a variable on self-reported income (categorized as <$10,000 per year, $10,000–$25,000, $25,000–$50,000 or greater than $50,000).

We included a binary variable for whether or not a respondent (or the respondent's household) owned a car since it was hypothesized that mobility increased the food choices available to respondents. It was also hypothesized that neighborhood food environments might have lesser relevance for individuals with greater mobility. Interaction terms with the neighborhood food environment variables were therefore included but not found to significantly improve the model and were omitted from the final models.

2.2.3. Food environment variables

To describe the food environments in which respondents lived, we included two types of variables in our models: (1) neighborhood food quality variables and (2) food store density variables. Food quality was defined as the ratio of shelf length of healthy foods to shelf length of junk foods. Shelf length amounts were summed across all stores in a geographic area surrounding a respondent's residence before creating the ratio. For all food environment variables, we examined successively larger radii of possible environments, starting with a radius of 500 m from a person's house and extending up to a radius of 2 km. These distances were calculated along the network of streets using ArcGIS 9.2 (Esri, 2009) and were chosen to approximate different levels of walkability, with 500 m being considered walkable and 2 km being deemed to require transport. Ratio variables were therefore constructed for each individual at 500 m, 1 km and 2 km. In all cases, the ratio of healthy food to junk food was less than one, meaning that junk food was always more predominant than healthy food. Even in the healthiest neighborhoods, the cumulative shelf space allocated to healthy food was approximately one-fourth that allocated to junk food. In the worst neighborhoods, the cumulative shelf space allocated to healthy food was less than one-twentieth that allocated to junk food.

In addition, to these continuous variables, we created a categorical variable disaggregating the food quality ratio into "low", "medium" and "high" groups – based on terciles of the healthy food to junk food ratio – and a further category for "undefined." This latter category was necessary because, for some individuals, there were no stores within certain radii, particularly for the smallest radius (500 m). As a result, there was neither healthy food nor junk food available in that food environment, and the resulting ratio of healthy food to junk food was undefined.

The same radii procedure was used to create variables indicating the presence of different types of food stores within specified distances of in respondents' homes. The econometric models then included variables representing a count of the number of supermarkets within specified radii to respondents' homes as well as a count of all other food stores (small and medium sized grocery stores, convenience stores, etc.).

It was recognized that the food environments defined by successively larger radii from respondents' homes might extend into neighboring tracts for which information on in-store contents had not been collected, necessitating the use of the OPH data base to identify stores in neighboring tracts. Information on the contents of those stores was imputed using a hot-deck imputation procedure which randomly assigned shelf-space from observed stores to similar stores in the neighboring tracts based on store type, store size, geographic location, and tract-level information (e.g., population density, percentage of population living below the poverty line) (Mander and Clayton, 2007).

2.2.4. Other neighborhood-level variables

We were concerned that the effects of food supply environment characteristics on subsequent obesity risk might be confounded by other characteristics of those environments. Two additional variables were therefore included to control for these possibilities: the percent of the population in the respondent's census tract who lived below the poverty line and the population density of those tracts. Following others (Morland et al., 2006; Black et al., 2010; Chen et al., 2010), the neighborhood poverty variable was intended to control for other unobservable characteristics of the neighborhood environment – crime, mobility, social norms regarding diet and health – as well as proxy for the types of food establishments that might choose to locate in certain neighborhoods. The variable for neighborhood population density was intended to serve as an indicator of commercial and residential activity in a neighborhood, including restaurants, which were not included in the data base of observed stores.

2.3. Statistical analysis.

We used bivariate analysis with χ^2 tests for significant associations between BMI status and three sets of potential influences: (1) individual-level characteristics, (2) neighborhood food environment characteristics (e.g., food quality and food store types), and (3) other neighborhood-level characteristics. Multinomial logistic regression (Greene, 2008) was used to estimate the influence of neighborhood food quality variables (i.e. the ratio of total shelf length allocated to healthy/junk food) and neighborhood food store density (i.e. counts of supermarkets, other food stores within specified radii of respondent households) on the risk that an individual was overweight or obese controlling for both individual- and neighborhood-level characteristics.

To test the robustness of our findings, two variations on this base model were then explored: (1) models including only the variables for neighborhood food quality or neighborhood food store types and (2) models with different distance radii (500 m and 2 km) to define the relevant food environments. The models with and without the food quality and store type variables were intended to assess their partial and joint effects, as well as to assess the sensitivity of the results to multi-collinearity. Interaction terms between store types and food quality were also included but were not statistically significant in any model and were dropped from the analysis.

To account for the hierarchical structure of our data – individuals nested within food neighborhoods – a two-level multinomial logistic model was estimated using the *gllamm* function for STATA 12.0 (Rabe-Hesketh et al., 2004). The likelihood was calculated using Guassian adaptive quadrature with 4 integration points (StataCorp; ESRI, 2007). To calculate prevalence estimates of obesity and overweight adjusted for model covariates, we used the *gllapred* command.

3. Results

3.1. Bivariate results

Table 1 describes the sample and presents the bivariate results comparing characteristics of respondents by BMI status. Overall, there was majority of females (66.1%) in the sample of respondents, which was split across racial lines (50% Caucasian, 42% African American, 5% Latino), household income (36% earned over $50,000 per year), and education levels (38% high school or below, 25% some college, and 37% college graduate). Just under one fifth of respondents reported that they never engaged in vigorous exercise, while 39% reported that they exercised at least 4 days per week.

Roughly 11% of the sample had no food stores within 1 km of their residence. The remaining 89% were then evenly divided into terciles based on the ratio of healthy to unhealthy food. Only one-quarter of respondents reportedly lived within a kilometer of a supermarket, but 89% had at least one other food store within the same distance.

Table 1 also shows the prevalence of overweight and obesity based on the background characteristics of respondents. Obesity was found to be positively associated with age, being African American or Latino and the percentage of a respondent's census tract population living below the poverty line. It was negatively associated with education and income.

Importantly, obesity was also related to the neighborhood food environment. Although having a supermarket within 1 km was not associated with a reduced prevalence of obesity, having more other food stores within 1 km was positively related to obesity; only 21.9% of respondents with no food stores within 1 km were reportedly obese versus 32.3% of respondents with 10 or more food stores within 1 km.

The relationship between neighborhood food quality and obesity was less straightforward. Only 24.2% of respondents in the highest food quality neighborhoods (i.e., with the highest ratio of healthy food to junk food) were reportedly obese, as compared with 34.5% of respondents in the medium food quality neighborhoods. However, respondents in the low food quality and no availability neighborhoods were also less likely to report obesity – 26.2% and 21.9% respectively. Non-linearities in the relationship between neighborhood food quality and obesity may be potentially explained by confounding with neighborhood wealth variables – the wealthiest households, for example, may be able to afford to live in exclusive neighborhoods absent commercial activity of any type. This issue is addressed in the multivariate analyses.

3.2. Multinomial logistic regression results

The multinomial logistic regression results (Table 2) support the hypothesis that the mix of healthy and unhealthy foods is a significant food environment characteristic explaining obesity. Individuals in areas with a high ratio of healthy to junk food within a kilometer of their residences were significantly less likely to be overweight (*RR* 0.546, 95% *CI* 0.328 to 0.907) or obese (*RR* 0.495, 95% *CI* 0.297 to 0.826). On the other hand, when controlling for the mix of healthy/unhealthy food in this geographic area, the number of supermarkets was *not* associated with being overweight (*RR* 1.386, 95% *CI* 0.812 to 2.366) or obese (*RR* 1.382, 95% *CI* 0.856 to 2.231). This result was similar for small food stores, which were also not associated with being overweight (*RR* 1.003, 95% *CI* 0.974 to 1.033) or obese (*RR* 1.020, 95% *CI* 0.993 to 1.047).

Respondents' income and education levels – once food environments and ethnicity were controlled for – appeared to have no statistically significant relationship to obesity, nor did the tract-level variable for the percent of the population below the poverty line (*RR* 1.343, 95% *CI* 0.287 to 6.281). Days of exercise per week – unsurprisingly – reduced the relative risk of being overweight (*RR* 0.969, 95% *CI* 0.948 to 0.990) but not obese (*RR* 0.980, 95% *CI*

Table 1
Individual demographic, exercise, and neighborhood characteristics of study sample.

	N	%	Overweight (%)	Obese (%)
Characteristic			Pct.	Pct.
Age				
18–30 years	246	19.8	26.8	21.5
30–50 years	532	42.8	30.8	26.7
50+ years	465	37.4	38.5	31.8***
Gender				
Male	822	33.9	28.1	27.5
Female	421	66.1	42.3	27.8***
Annual income				
< $10,000	192	15.5	29.2	35.4
$10,000-$25,000	306	24.6	36.3	31.1
$25,000-$50,000	302	24.3	30.8	26.5
> $50,000	443	35.6	33.6	22.6**
Education				
Did not complete high school	112	9.0	37.5	32.1
High school	355	28.6	31.3	33.2
Some college	310	24.9	34.8	27.4
College graduate	466	37.5	31.8	22.3**
Ethnicity				
Caucasian	626	50.4	32.4	20.6
African American	522	42.0	33.0	36.8
Latino	57	4.6	38.6	28.1
Other	38	3.1	31.6	15.8***
No. of days of vigorous exercise				
None	236	19.0	30.5	37.3
1–3 days	524	42.2	34.5	27.9
4–6 days	341	27.4	33.7	23.2
Daily	142	11.4	28.9	21.1***
% of census track below poverty line				
Low	420	33.8	32.1	22.1
Medium	425	34.2	35.8	25.2
High	398	32.0	30.7	35.9***
Population density in tract				
Low	48	3.9	25.0	33.3
Medium	644	51.8	32.5	26.9
High	551	44.3	34.1	28.0
Neighborhood food quality[a]				
No ratio	137	11.0	24.8	21.9
Low	367	29.5	36.2	26.2
Medium	371	29.9	32.1	34.5
High	368	29.6	33.4	24.2***
Supermarkets within 1 K				
No	930	74.8	32.5	28.2
Yes	313	25.2	34.2	25.9
Number of other stores within 1 K				
None	137	11.0	24.8	21.9
1–3	349	28.1	33.8	25.8
4–6	313	25.2	32.9	27.2
7–9	212	17.1	34.9	29.7
10+	232	18.7	34.5	32.3*
Total	1243	100.0	32.9	27.6

P value for differences between distributions of subgroups using chi-square tests for proportions and analysis of variance for means.

*** $P < 0.001$.
** $P < 0.01$.
* $P < 0.05$.
[a] Neighborhood food quality is based on the ratio of shelf space of healthy foods (fruits and vegetables) to energy-dense snack foods (chips, candies, sodas, and pastries) in all stores within 1 km of the respondent's residence.

Table 2
Multinomial logistic regression results using food environment measures (1-k neighborhoods).

	Overweight			Obese		
Variable	RR	95% CI		RR	95% CI	
Age (base=‘18-30’)	1.000			1.000		
30–50 years	1.431	(0.999	2.050	1.481*	1.016	2.159
Older than 50 years	2.903*	1.993	4.227	2.870***	1.935	4.259
Female	0.375***	0.281	0.501	0.510***	0.373	0.695
Income (Base= < $25 K)	1.000					
$25 K–$50 K	0.748	0.504	1.110	0.898	0.596	1.354
> $50 K	0.912	0.613	1.356	0.943	0.615	1.446
Education (Base=High school or less)	1.000					
Some college	1.022	0.703	1.485	0.928	0.629	1.370
College graduate	0.801	0.550	1.187	0.756	0.508	1.125
race (base=white)	1.000					
African American	1.797***	1.255	2.630	2.524***	1.735	3.672
Latino	1.911	0.967	3.778	1.939	0.938	4.010
Household owns a car	1.365	0.901	2.068	0.764	0.508	1.149
Days of exercise per week	0.968	0.971	1.035	0.967	0.946	1.007
% of tract below poverty line	0.784	0.194	3.175	0.912	0.211	3.952
Tract pop. density	1.006	0.957	1.057	0.970	0.920	1.023
Neighborhood food quality [a]						
No ratio	0.420***	0.252	0.701	0.561*	0.302	0.882
Middle ratio	0.755	0.505	1.130	0.883	0.582	1.344
High ratio	0.532**	0.313	0.907	0.474**	0.269	0.836
Store density						
No. of small stores within radius	1.002	0.971	1.035	1.019	0.987	1.052
No. of supermarkets within radius	1.373	0.838	2.250	1.327	0.791	2.229
N	1243					

*** $P<0.001$.
** $P<0.01$.
* $P<0.05$.
[a] Neighborhood food quality is based on the ratio of shelf space of healthy foods (fruits and vegetables) to energy-dense snack foods (chips, candies, sodas, and pastries) in all stores within 1 km of the respondent's residence.

0.934 to 1.029). Importantly, race – both African American (*RR* 2.741, 95% *CI* 1.850 to 4.060) and Latino (*RR* 2.141, 95% *CI* 1.033 to 4.437) – significantly increased the risk of being obese relative to white/Caucasian respondents.

To test the robustness of our findings and to attempt to replicate models elsewhere in the literature which have focused solely on store types rather than store contents, we estimated two additional types of models: models with food quality variables alone (i.e. the ratio of healthy to unhealthy food) and models with only the store density variables (i.e., number of supermarkets and number of other food stores). Each set of models contained the same set of demographic and socioeconomic control variables as in the earlier full models described in Table 2. The relative risk ratios for the food environment variables for each of these models, including the full models, are presented in Table 3. Models were also estimated using different neighborhood definitions—radii of 500 m from the household and 2 km from the household.

Importantly, it was found that the food quality result was robust to the neighborhood definition used, while the store density variables showed very little association with overweight and obese at any distance. For example, being in a high quality food neighborhood using the 2 km radius – and controlling for store types – was negatively associated with overweight (*RR* 0.549, $P=0.009$) and obese (*RR* 0.606, $P=0.069$). This result was suggestive using the 500 m neighborhood definition (Overweight *RR* 0.695, $P=0.117$; Obese *RR* 0.754, $P=0.236$). The lack of statistical significance in the latter result is unsurprising given the relative lack of commercial activity within 500 m of many respondents' residences.

In none of the models – with or without food quality variables – was the presence of a supermarket negatively associated with overweight or obese. The number of small food stores did have a limited association with obesity. Using the 500 m neighborhood definition and the model with only the store density variables (Model 2), the number of small food stores was positively associated with obesity (*RR* 1.091, $P=0.018$), a result that was similar at 1 km (*RR* 1.031, $P=0.028$).

To provide a more intuitive sense of the magnitude of the effect of food environments on the relative risk of being overweight or obese, the predicted probabilities for each category of BMI status from the multinomial logistic regression models are presented in Fig. 1 for the full model at 1 km. For example, being in an unhealthy food environment (i.e. low healthy food to junk food ratio) increased the likelihood of being overweight relative to a healthy food environment by 7.4 percentage points (38.6% versus 31.2%) and of being obese by 7.9 percentage points (30.0% versus 22.1%). People in unhealthy food environments were a full 15 percentage points (31.4% versus 46.7%) less likely to be of normal weight relative to those in the healthier environments.

4. Discussion

This work has expanded upon current measures of the food environment by using indicators of store contents in addition to the common practice of incorporating store type variables. The result that obesity is likely associated with the quality of the food environment is consistent with much of the existing literature (Zenk et al., 2005; Morland et al., 2006; Moore et al., 2008; Morland and Evenson, 2009; Chen and Florax, 2010), but the new finding here is that relative quantities of healthy and unhealthy food in a neighborhood may be a better way to describe a food environment, than merely using counts of store types.

Table 3
Relative risk for overweight and obesity attributable to neighborhood food environment variables, multinomial logistic models with and without neighborhood food quality and store density variables [a] ($N=1243$).

	Overweight			Obese		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
500 km						
Neighborhood food quality [b]						
No ratio	0.991		1.186	0.741		0.851
Middle ratio	1.140		1.071	1.162		1.130
High ratio	0.855		0.695	0.777		0.754
Store density						
No. of small stores within radii		1.055	1.095		1.091*	1.076
No. of supermarkets within radii		1.105	1.504		0.794	0.952
1 km						
NEIGHBORHOOD FOOD QUALITY [B]						
No ratio	0.436***		0.442**	0.536*		0.573*
Middle ratio	0.821		0.770	1.013		0.916
High ratio	0.708*		0.546*	0.655*		0.495**
Store density						
No. of small stores within radii		1.014	1.003		1.031*	1.020
No. of supermarkets within radii		1.010	1.386		0.886	1.382
2 km						
Neighborhood food quality: [b]						
No ratio						
Middle ratio	1.049		0.860	1.067		0.842
High ratio	0.712*		0.549**	0.777		0.606
Store density						
No. of small stores within radii		0.995	0.993		1.002	1.000
No. of supermarkets within radii		1.068	1.518		1.031	1.404

* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.
[a] Results in the third data column are for the full model (Model 3) at 1 km. The complete set of statistics on this model are displayed in Table 2. Model 1 includes food quality variables and Model 2 includes store density variables. All models include the same control variables used in Table 2: age, gender, education, income, race, car ownership, days of exercise, percentage of census tract below poverty line, census tract population density.
[b] Neighborhood food quality is based on the ratio of shelf space of healthy foods (fruits and vegetables) to energy-dense snack foods (chips, candies, sodas, and pastries) in all stores within defined distances of respondents' residences.

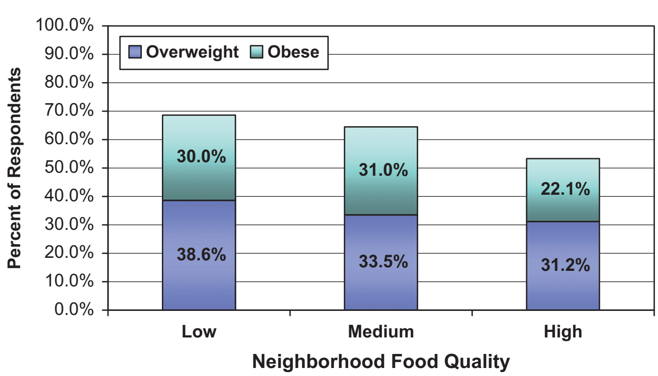

Fig. 1. Predicted BMI Categories from Multinomial Logit Models, [†]Stratified by Neighborhood Food Quality[††] for the 1 km Neighborhood.
[†]Predictions have been adjusted for all control variables in the model displayed in Table 2.
[††] Neighborhood food quality is based on the ratio of shelf space of healthy foods (fruits and vegetables) to energy-dense snack foods (chips, candies, sodas, and pastries) in all stores within a 1 km of the respondent's residence.

In this analysis, it was found that the presence of supermarkets had no association with the risk of being overweight or obese at any distance in either the models with the food density variables alone (Model 2) or in the combined models with food quality and food density variables (Model 3). On the other hand, it was found that the effects of the ratio variables for food quality were statistically significant regardless of whether the store density variables were included or not. In short, it is not supermarkets per se that influence obesity but rather their ability to shift the balance towards healthy food options in environments where they are located.

There are several potential limitations to this work. First, we relied on self-reported heights and weights. But this is a common practice in food environment research that relies on telephone surveys, and there is little reason to believe that biases in reporting of weight would be correlated with the neighborhood food environment. Our in-store measures were restricted to linear shelf length, which approximates the prominence of a food type within a store, and thus the likelihood that a shopper will be exposed to it (Farley et al., 2009). We did not, however, take measures on the depth or height of shelves, so our measure must be considered a proxy for total shelf space. Admittedly, our measures of healthy food and junk food are not comprehensive, and future work should expand upon the limited measures of in-store contents that we have used here. Finally, we did not include information on other characteristics that could affect purchases, such as item cost or quality.

As with previous food environment research, we unfortunately do not have information regarding where our respondents shopped. This study was conducted in urban neighborhoods in Southeast Louisiana, which are not unlike other older U.S. neighborhoods in the south and east of the country. But generalizability of the findings beyond the U.S. may be limited. There is less evidence for neighborhood effects on obesity in other countries, a conundrum which has been explored by Cummins and Macintyre (2006). Finally, owing to the cross-sectional nature of this study, we cannot infer causality from our associations of the food environment with obesity.

This paper adds additional evidence on the importance of the food environment for consumer behavior and weight status. With a more nuanced description of the food environment that includes data on store type and in-store contents within defined distances of respondents' residences, we have shown that the mix of healthy and unhealthy foods in a neighborhood is a better predictor of overweight status, than the density of store types. Given the limitations described above, more research on this nascent approach is needed. Natural experiments involving the introduction of supermarkets into previously under-served locations have shown mixed results (Wrigley et al., 2003; Cummins et al., 2005) but similar quasi-experimental designs involving re-allocating shelf space within existing stores may prove more promising (Petticrew et al., 2005).

Should our results be corroborated by others, they would have important implications for food policy. Not all supermarkets carry the same mix of healthy foods, and not every neighborhood can support a supermarket. The balance of healthy foods in a neighborhood can be improved by bringing new mid-sized groceries, by retrofitting existing small stores with greater amounts of produce, and/or lesser amounts of energy-dense snack foods, or by shifting the mix of these foods in supermarkets for neighborhoods that have them. Thus, policy approaches to address an imbalanced access to healthy foods could be tailored to the needs of specific neighborhoods.

Acknowledgments

The authors thank Thomas A. Farley and Deborah A. Cohen who were co-investigators of an earlier study that generated much of the data used in this paper.

References

Black, J.L., Macinko, J., et al., 2010. Neighborhoods and obesity in New York City. Health Place 16 (3), 489–499.

Block, D., Kouba, J., 2006. A comparison of the availability and affordability of a market basket in two communities in the Chicago area. Public Health Nutrition 9 (7), 837–845.

Bodor, J.N., Rice, J.C., et al., 2010. The association between obesity and urban food environments. Journal of Urban Health 87 (5), 771–781.

Bodor, J.N., Rose, D., et al., 2008. Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. Public Health Nutrition 11 (4), 413–420.

Boone-Heinonen, J., Gordon-Larsen, P., et al., 2011. Fast Food Restaurants and Food Stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. Archives of Internal Medicine 171 (13), 1162–1170.

Cheadle, A., Psaty, B.M., et al., 1991. Community-level comparisons between the grocery store environment and individual dietary practices. Preventive Medicine 20 (2), 250–261.

Chen, S., Florax, R.J., et al., 2010. Obesity and access to chain grocers. Economy Geography 86 (4), 431–452.

Chen, S.E., Florax, R.J., 2010. Zoning for health: the obesity epidemic and opportunities for local policy intervention. Journal of Nutrition 140 (6), 1181–1184.

Clearwater Research, I., 2005. Rand Alcohol Phone Survey of Los Angeles County and Louisiana State: Technical Report. Boise, Clearwater Research, Inc.

Connell, C.L., Yadrick, M.K., et al., 2007. Food supply adequacy in the Lower Mississippi Delta. Journal of Nutrition Education and Behavior 39 (2), 77–83.

Cummins, S., Macintyre, S., 2006. Food environments and obesity—neighbourhood or nation? International Journal of Epidemiology 35 (1), 100–104.

Cummins, S., Petticrew, M., et al., 2005. Large scale food retailing as an intervention for diet and health: quasi-experimental evaluation of a natural experiment. J Epidemiology and Community Health 59 (12), 1035–1040.

Edmonds, J., Baranowski, T., et al., 2001. Ecological and socioeconomic correlates of fruit, juice, and vegetable consumption among African-American boys. Preventive Medicine 32 (6), 476–481.

ESRI, 2007. 2007/2012 Demographic Data. Redlands, CA.

Esri, 2009. ArcGIS 9.2. Redlands, CA.

Farley, T.A., Rice, J., et al., 2009. Measuring the food environment: shelf space of fruits, vegetables, and snack foods in stores. Journal of Urban Health 86 (5), 672–682.

Franco, M., Diez-Roux, A.V., et al., 2009. Availability of healthy foods and dietary patterns: the multi-ethnic study of atherosclerosis. American Journal of Clinical Nutrition 89 (3), 897–904.

Gordon, C., Purciel-Hill, M., et al., 2011. Measuring food deserts in New York City's low-income neighborhoods. Health Place 17 (2), 696–700.

Greene, W.H., 2008. Econometric Analysis. Prentice-Hall, Upper Saddle River, NJ.

Inagami, S., Cohen, D.A., et al., 2006. You are where you shop: grocery store locations, weight, and neighborhoods. American Journal of Preventive Medicine 31 (1), 10–17.

Kumar, S., S.C. Quinn, et al. (2010). Food is directed to the area: African Americans' perceptions of the neighborhood nutrition environment in Pittsburgh. Health Place.

Leung, C.W., Laraia, B.A., et al., 2011. The influence of neighborhood food stores on change in young girls' body mass index. American Journal of Preventive Medicine 41 (1), 43–51.

Lopez, R.P., 2007. Neighborhood risk factors for obesity. Obesity (Silver Spring) 15 (8), 2111–2119.

Mander, A., Clayton, D., 2007. HOTDECK: Stata module to impute missing values using the hotdeck method.

Moore, L.V., Diez-Roux, A.V., et al., 2008. Associations of the local food environment with diet quality—a comparison of assessments based on surveys and geographic information systems, the multi-ethnic study of atherosclerosis. American Journal of Epidemiology 167 (8), 917–924.

Morland, K., Roux, A.V.Diez, et al., 2006. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. American Journal of Preventive Medicine 30 (4), 333–339.

Morland, K., Wing, S., et al., 2002. Neighborhood characteristics associated with the location of food stores and food service places. American Journal of Preventive Medicine 22 (1), 23–29.

Morland, K.B., Evenson, K.R., 2009. Obesity prevalence and the local food environment. Health Place 15 (2), 491–495.

Pearce, J., Hiscock, R., et al., 2008. The contextual effects of neighbourhood access to supermarkets and convenience stores on individual fruit and vegetable consumption. Journal of Epidemiology and Community Health 62 (3), 198–201.

Petticrew, M., Cummins, S., et al., 2005. Natural experiments: an underused tool for public health? Public Health 119 (9), 751–757.

Powell, L.M., Auld, M.C., et al., 2007. Associations between access to food stores and adolescent body mass index. American Journal of Preventive Medicine 33 (4 Suppl), S301–S307.

Rabe-Hesketh, S., Skrondal, A., 2005. Multilevel and Longitudinal Modeling Using Stata. College Station, Texas, StataCorp. LP.

Rabe-Hesketh, S., A. Skrondal, et al., 2004. GLLAMM Manual. U.C. Berkeley Division of Biostatistics Working Paper Series. Berkeley, CA.

Rose, D., Bodor, J.N., et al., 2010. The importance of a multi-dimensional approach for studying the links between food access and consumption. Journal of Nutrition 140 (6), 1170–1174.

Rose, D., Hutchinson, P.L., et al., 2009. Neighborhood food environments and Body Mass Index: the importance of in-store contents. American Journal of Preventive Medicine 37 (3), 214–219.

Rose, D., Richards, R., 2004. Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. Public Health Nutrition 7, 1081–1088.

StataCorp Stata/SE 11.0. College Station, TX.

Walker, R.E., Keane, C.R., et al., 2010. Disparities and access to healthy food in the United States: a review of food deserts literature. Health Place 16 (5), 876–884.

Wrigley, N., Warm, D., et al., 2003. Deprivation, diet, and food retail access: findings from the leeds 'food-deserts' study. Environment and Planning A 35, 151–188.

Zenk, S.N., Lachance, L.L., et al., 2009. Neighborhood retail food environment and fruit and vegetable intake in a multiethnic urban population. American Journal of Health Promotion 23 (4), 255–264.

Zenk, S.N., Schulz, A.J., et al., 2005. Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. American Journal of Public Health 95 (4), 660–667.