Distance to Store, Food Prices, and Obesity in Urban Food Deserts

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Background: Lack of access to healthy foods may explain why residents of low-income neighborhoods and African Americans in the U.S. have high rates of obesity. The findings on where people shop and how that may influence health are mixed. However, multiple policy initiatives are underway to increase access in communities that currently lack healthy options. Few studies have simultaneously measured obesity, distance, and prices of the store used for primary food shopping.

Purpose: To examine the relationship among distance to store, food prices, and obesity.

Methods: The Pittsburgh Hill/Homewood Research on Eating, Shopping, and Health study conducted baseline interviews with 1,372 households between May and December 2011 in two low-income, majority African American neighborhoods without a supermarket. Audits of 16 stores where participants reported doing their major food shopping were conducted. Data were analyzed between February 2012 and February 2013.

Results: Distance to store and prices were positively associated with obesity ($p<0.05$). When distance to store and food prices were jointly modeled, only prices remained significant ($p<0.01$), with higher prices predicting a lower likelihood of obesity. Although low- and high-price stores did not differ in availability, they significantly differed in their display and marketing of junk foods relative to healthy foods.

Conclusions: Placing supermarkets in food deserts to improve access may not be as important as simultaneously offering better prices for healthy foods relative to junk foods, actively marketing healthy foods, and enabling consumers to resist the influence of junk food marketing.
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Introduction

It is well established that residents of low-income neighborhoods and African Americans in the U.S. have poorer health and higher rates of obesity.[1–3] Low-income and predominantly African American neighborhoods (regardless of income) are less likely to have access to a supermarket relative to higher-income and white neighborhoods,[4,5] and it is hypothesized that distance to a supermarket may be an underlying cause of obesity and other health disparities.[6–12] A study[13] of 10,763 residents in four states found that the presence of supermarkets in the residential census tract was associated with a 24% lower prevalence of obesity and a 9% lower prevalence of overweight. Another study[14] of a national sample of 60,775 women aged 50–79 years found that higher density of supermarkets within 0.5 miles of a person's residence was associated with lower BMI.

However, the availability of establishments that offer healthy foods does not guarantee that residents will in fact shop there. Research[15–17] has shown that residents, specifically those of low income, often shop outside their neighborhoods of residence. Another way to examine the influence of supermarkets on health outcomes is to focus on characteristics of the store where people actually shop.

Indeed, store choice may reflect individual factors (e.g., income) and store characteristics such as the availability, quality, pricing, and point-of-sale advertising of food.[18–22]

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By examining travel distance and collecting store audits, several studies have attempted to identify store characteristics that may impact health. However, research findings are mixed. Two studies[23,24] found no association between distance to the store where people did their major food shopping and BMI. Shopping at a discount store has been associated with higher BMI.[15,25] Shopping at a store located in a neighborhood with low-SES residents has also been associated with higher BMI.[26] Another two studies[24,27] found no relationship between in-store characteristics (e.g., summary score of quality, availability, and price of food; availability of fruits, vegetables, and cereals) and BMI.

Some studies have focused specifically on store prices[28] and found mixed relationships between price, consumption, and body weight. A few studies[22,29,30] have found that high food prices in low-income neighborhoods are a barrier to access, especially for healthy foods. One study[31] found that lowering prices of healthy foods through a rebate program led to increases in purchases of healthy foods and decreases in purchases of non-nutritious foods. Another study[24] that surveyed adults at selected supermarkets in Vancouver, Canada, found an inverse relationship between the market basket price of the supermarket and BMI from self-reported height and weight.

Only one U.S. study[32] has simultaneously measured travel distance and food prices of the supermarket most used in relation to obesity. Although distance to the supermarket where people shopped did not predict obesity risk, patrons of high-price supermarkets had obesity rates (9%) that were one third that among patrons of low-price supermarkets (27%).

Because multiple policy initiatives (e.g., Healthy Food Financing) are under way to increase access to healthy, affordable foods in "food deserts,"[10,33] it is critical to assess whether this approach is likely to address the obesity epidemic.[34,35] Drawing on baseline data from the Pittsburgh Hill/Homewood Research on Eating, Shopping, and Health (PHRESH) study, distance to store and store prices were tested as predictors of obesity among residents of low-income neighborhoods. Differences in store characteristics (e.g., availability, marketing) were explored as potential explanations for significant relationships.

Methods

Design and Sample

PHRESH is a 5-year study of two predominantly African American, low-income "food deserts"[36] in Pittsburgh, Pennsylvania, with one neighborhood obtaining a new supermarket during the study period. Baseline interviews, prior to the supermarket's opening, were conducted between May and December 2011. The sample of households was drawn from a list of addresses generated by the Pittsburgh Neighborhood and Community Information System, with stratified sampling in the intervention neighborhood. Out of 4,002 sampled addresses, 2,900 households were not vacant. A household member was contacted in 1,956 addresses, with up to ten attempts per household. The primary food shopper in 1,372 households completed an interview. The study also conducted baseline audits of stores where residents reported doing major shopping. The study protocol was approved by the RAND Human Subjects Protection Committee.

Household Surveys

The PHRESH survey collected information on food shopping behaviors and preferences, transportation options, socioeconomic and demographic information, and interviewer-measured height and weight. Height was measured to the nearest eighth inch using a carpenter's square (triangle) and an 8-foot folding wooden ruler marked in inches. Body weight was measured using the SECA Robusta 813 digital scale to the nearest tenth of a pound. BMI was calculated using standard formula, with a BMI of 30 or greater indicating obesity.

Participant characteristics included: age, gender, race/ethnicity, education level, household income, marital status, number of children and adults in household, and car access (own, lease, or borrow car). Income was measured with a nine-category ordinal scale and recoded to the interval midpoint. Adjusted income was computed as a ratio of household income and size.

Survey participants were asked for their home address and the name and location of their major food shopping store for street network distance measures. "Major food shopping store" was identified by asking, *What is the name and address of the main store where you most often do your major food shopping?* Addresses were geocoded to a position along the street network using the 10.0 U.S. Streets Address Locator within ArcGIS 10 (ESRI, Redlands CA). Street network distances in miles were computed from each respondent's home to their major food shopping store, using the shortest route participants could drive along the existing road network.

Store Audits

Food audits were conducted in all 24 food stores inside the neighborhoods; a small number of participants indicated doing their major food shopping at a store within the neighborhood. Audits of 16 stores outside the neighborhoods where most participants reported doing major food shopping were conducted (top ten responses for stores from survey participants in each neighborhood were examined). Adapted from the Bridging the Gap Food Store Observation Form,[37] the audit collected information on availability, in-store marketing strategies, and prices of different food items.

Four measures of price (food staple prices, junk food prices, fruit and vegetable prices, and standardized price index [SPI]) and two measures of marketing (in-store store displays and dominant view from the store's main entrance) were derived. With the exception of chips and cereal for which prices were recorded for a particular brand, price data reflect the least expensive option for a product category.

The food staple prices index is the sum of prices of five standard items that were available in all stores: a dozen eggs, half gallon of whole milk, 20-ounce loaf of white bread, 15–18-ounce box of high-sugar cereal (i.e., 6 g or more of sugar per serving), and 15–18-ounce box of low-sugar cereal (i.e., <6 g per serving). The junk food prices index is the sum of the least expensive soda unit price multiplied by 67.6 ounces for a two-liter family-size bottle of soda, and the least expensive unit price for an 11-ounce bag of chips. The fruit and vegetable price index is the total price paid for a pound each of six items: apples, bananas, lettuce, oranges, potatoes, and tomatoes. In one store where produce was sold by the piece, we used U.S. Department of Agriculture product weights to convert per-item prices to per-pound prices (ndb.nal.usda.gov/ndb/search/list). The three price indices were converted into z-scores by subtracting the mean and dividing by the SD to convert them to a scale with the same mean (0) and SD (1). The z-scores were summed to create a store-level SPI.

Availability of 22 fresh fruits and vegetables, commonly consumed in the U.S. population (e.g., apples, carrots) and culturally specific items commonly consumed in African American populations (e.g., okra, greens)[38] was assessed at each store. This index indicates the number of items on this list of 22 fresh fruits and vegetables sold in the store. Availability of nine sugar-sweetened beverages (SSBs) and snack items was assessed: regular-size soft drink, regular-size diet soft drink, individual-size salted potato chips, family-size salted potato chips, individual-size spicy chips, family-size spicy chips, snack cakes, cookies, and candy. This index indicates the number of SSBs and snacks sold in the store.

The audit tool recorded which food product dominated the view from the store's main entrance: fruit, vegetables, SSBs, candy/sweet baked goods, or salty snacks. We created two binary indicator variables to capture whether *healthy foods* (fruits/vegetables) or *junk foods* (SSBs/candy/sweet baked goods/salty snacks) dominated the view. The audit recorded the number of end-aisle, special floor, and cash register displays that promoted the following three food groups: (1) fruits and vegetables with no added fat, sugar, or salt and products with 50% whole grains (*healthy foods*); (2) SSBs; and (3) salty snacks, candy, or sweetened baked goods. We used these counts to produce two display variables. The *healthy food display* and *junk food display* variables represent the total number of end-aisle, special floor, and cash register displays that promote healthy foods and junk foods (SSBs/salty snacks/candy/sweetened baked goods), respectively.

Data Analysis

For the 1,214 participants who completed an interview and shopped at an audited store, descriptive statistics were computed to explore associations among obesity, sociodemographic characteristics, distance to store, and store food prices (measured by SPI). Significant differences were tested using t-tests and chi-square tests. To explore the bivariate relationship between distance to store and SPI, correlations were computed and tested for significance.

Multivariate logistic regression models were used to examine the relationship among obesity, distance to store, and SPI. The dependent variable was whether or not the study participant was obese. In Model 1, the association between demographic characteristics and obesity was explored. In Model 2, the association between distance and obesity was explored. In Model 3, the association between SPI and obesity was explored. In Model 4, the association between SPI and obesity, after adding distance to the model, was explored. Covariates included age, age squared, being male, education (less than high school is the omitted category), adjusted household income, living in a household with kids, marital status, car access, and an indicator of neighborhood (Homewood).

Analyses were performed in SAS software, version 9.2, of the SAS System for Windows (SAS Institute, Inc., Cary NC). An α of 0.05 or less was used to determine significance. Data were cleaned and analyzed from February 2012 to February 2013.

Results

Characteristics of Study Participants

Of the 1,214 study participants, 73% were female, 90% were non-Hispanic black, 48% were aged less than 54 years, and about half had the equivalent of a high school degree or less (Table 1). The median household income was $13,373. Almost half (46%) of the sample was obese, compared to a national estimate of 38.7% for a population matched on gender and race/ethnicity. Obese participants were more likely to be women, non-Hispanic black, educated at the level of some college or less, living in a household with kids, and have a lower adjusted income relative to non-obese participants. Also, obese participants lived at an average distance of 3.5 miles from their major shopping store compared to 3.0 miles among non-obese participants.[39]

Sociodemographics, Distance to Store, and Food Prices

In the second panel of Table 2, participants who traveled more or less than the median distance were contrasted. Primary food shoppers who were female, lived in a household with kids, and had car access were more likely to travel farther for major food shopping. In the third panel of Table 2, participants that shopped at a store with SPI below versus above the median value were compared. Participants who were younger, married, living in a household with kids, and had car access were more likely to shop at a low-price store.

The three food price indices were strongly, positively correlated (Table 3, r=0.67 to 0.78). Distance from a respondent's home to a major food shopping store was inversely correlated with food prices (r=–0.35 to –0.64), with fruit and vegetable prices being most strongly correlated with distance. SPI was positively correlated with the three individual indices, and inversely correlated with distance (r=–0.69).

Obesity, Distance to Store, and Food Prices

The following participant characteristics of age, age-squared, living in a household with kids, being female,

Table 1. Characteristics of participants (n=1,214), n (%) unless otherwise noted

	Total participants (n=1,214)	Obese participants (n=564; 46.5%)	Non-obese participants (n=650; 53.5%)
Age (years)			
18–34	198 (16.3)	96 (17.0)	102 (15.7)
35–54	383 (31.6)	192 (34.0)	191 (29.4)
55–74	452 (37.2)	207 (36.7)	245 (37.7)
≥75	181 (14.9)	69 (12.2)	112 (17.2)
Gender			
Male	324 (26.7)	**109 (19.3)****	**215 (33.1)****
Female	890 (73.3)	455 (80.7)	435 (66.9)
Race-ethnicity			
Black	1,092 (90.0)	**519 (92.0)****	**573 (88.2)****
Mixed-black	42 (3.5)	19 (3.4)	23 (3.5)
Other	72 (5.9)	21 (3.7)	51 (7.8)
Missing	8 (0.7)	5 (0.9)	3 (0.5)
Education			
Less than high school	187 (15.4)	**85 (15.1)****	**102 (15.7)****
High school	451 (37.2)	207 (36.7)	244 (37.5)
Some college	393 (32.4)	205 (36.4)	188 (28.9)
College	183 (15.1)	67 (11.9)	116 (17.9)
Per capita household income			
<5,000	182 (15.0)	**103 (18.3)***	**79 (12.2)***
5,000–9,999	436 (35.9)	199 (35.3)	237 (36.5)
10,000–19,999	367 (30.2)	172 (30.5)	195 (30.0)
20,000–100,000	229 (18.9)	90 (16.0)	139 (21.4)
Marital status			
Married or with partner	215 (17.7)	104 (18.4)	111 (17.1)
Never married	510 (42.0)	244 (43.3)	266 (40.9)
Widowed/divorced/single	489 (40.3)	216 (38.3)	273 (42.0)
Household with kids	302 (24.9)	**175 (31.0)****	**127 (19.5)****
Own or have access to a car	672 (55.7)	323 (57.3)	349 (54.3)
Average distance from home to major store[a]	3.3 (3.0)	**3.5 (3.2)***	**3.0 (2.7)***

Note: Boldface indicates statistical significance. Sample sizes reflect the total number of people who responded to the relevant survey questions.
[a]Continuous variable, M (SD).
*$p<0.05$, **$p<0.01$.

and education less than college were positively associated ($p<0.05$) with obesity in all models (Table 4). In Model 2, there was a significant positive association between obesity and distance, after adjusting for sociodemographic characteristics. For every additional mile traveled to shop, the odds of being obese increased by 5% ($p<0.05$). In Model 3, a significant inverse adjusted association between obesity and SPI ($p<0.01$) was observed. In Model 4, the relationship between obesity and distance was non-significant, whereas the

Table 2. Characteristics of participants (n=1,214) by distance and price, %

	All	Distance ≤ Median	Distance > Median	SPI ≤ Median	SPI > Median
Age (years)					
18–34	16.3	13.8	18.8	**23.6****	**14.0****
35–54	31.6	32.3	30.8	**38.7****	**29.3****
55–74	37.2	38.6	35.9	**28.1****	**40.1****
≥75	14.9	15.3	14.5	**9.6****	**16.6****
Gender					
Male	26.7	**29.5***	**23.9***	23.0	27.9
Female	73.3	**70.5***	**76.1***	77.1	72.1
Race-ethnicity					
Black	90.0	89.3	90.6	91.4	89.5
Mixed-black	3.5	3.8	3.1	5.5	2.8
Other	5.9	6.3	5.6	2.4	7.0
Missing	0.7	0.7	0.7	0.7	0.7
Education					
Less than high school	15.4	16.3	14.5	13.0	16.2
High school	37.2	37.6	36.7	36.3	37.4
Some college	32.4	31.3	33.4	36.6	31.0
College	15.1	14.8	15.3	14.0	15.4
Per capita household income ($)					
<5,000	15.0	16.4	13.3	17.5	14.2
5,000–9,999	35.9	34.3	37.6	39.7	34.7
10,000–19,999	30.2	31.5	29.0	26.4	31.5
≥20,000	18.9	17.6	20.1	16.4	19.6
Marital status					
Married or with partner	17.7	16.6	18.8	**23.0****	**16.1****
Never married	42.0	40.5	43.5	**47.3****	**40.4****
Widowed/separated/single	40.3	42.9	37.7	**29.7****	**43.5****
Household with kids	24.9	**22.2***	**27.5***	**37.3****	**20.9****
Own or have access to a car	55.7	**50.8****	**60.5****	**69.4****	**51.3****

Note: Boldface indicates statistical significance. Sample sizes reflect the total number of people who responded to the relevant survey questions.
*$p<0.05$, **$p<0.01$.
SPI, standardized price index.

relationship between SPI and obesity remained statistically significant—shopping at a store with 1 SD higher prices was associated with 36% lower odds of being obese.

In additional modeling not shown here, the three price indices were entered separately, adjusting for sociodemographic covariates. The regression coefficients from the three models with a single price index (Model 3), and then with price and distance in the model (Model 4), were 0.85 and 0.87 for staple prices ($p<0.001$); 0.76 and 0.77 for junk food prices ($p<0.01$); and 0.75 and 0.78 for fruit/vegetable prices ($p<0.001$), respectively.

Table 3. Correlations between distance to store and food prices

	Distance to store	SPI	Price of staples	Price of junk food	Price of fruits/ vegetables
Distance to store	1.00	**−0.69****	**−0.35****	**−0.51****	**−0.64****
SPI		1.00	**0.85****	**0.89****	**0.93****
Price of staples			1.00	**0.78****	**0.75****
Price of junk food				1.00	**0.67****
Price of fruits/ vegetables					1.00

Note: Boldface indicates statistical significance.
** $p<0.01$.
SPI, Standardized price index.

Characteristics of Low-Price versus High-Price Stores

Half of the stores where participants shopped (*n*=8) were full-service supermarkets. The high-price stores included full-service supermarkets and a specialty grocery store. The low-price stores also included two discount grocery stores, two supercenters, two meat/seafood markets, and one wholesale club. Table 5 indicates that low-price stores offered 18 fruits/vegetables and seven junk foods, whereas high-price stores offered 21 fruits/vegetables and eight junk foods, on average. Fruits/vegetables dominated the view from the main entrance in 14% of low-price and 71% of high-price stores. By contrast, junk foods (SSBs, candy, or salty snacks) dominated the view from the main entrance in 67% of low-price and 33% of high-price stores. On average, low-price stores had 7.7 displays to promote healthy foods while high-price stores had 20.2 displays of healthy foods, more than a 2-fold difference.

Discussion

An underlying tenet of the Healthy Food Financing Initiative, a $400-million investment intended to bring affordable healthy foods to food deserts, is that the lack of access to healthy foods is an important cause of obesity and chronic disease among minority populations. In this study, most residents of these food deserts

Table 4. Association between obesity, store network distance, and standardized price index, OR (95% CI)

	Model 1	Model 2	Model 3	Model 4
Distance to store		**1.05 (1.01, 1.10)***		0.93 (0.85, 1.01)
SPI			**0.79 (0.70, 0.89)****	**0.65 (0.50, 0.84)****
Covariates				
Age	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)
Age-squared	**1.00 (1.00, 1.00)****	**1.00 (1.00, 1.00)****	**1.00 (1.00, 1.00)****	**1.00 (1.00, 1.00)****
Male	**0.51 (0.39, 0.68)****	**0.52 (0.39, 0.68)****	**0.52 (0.39, 0.69)****	**0.52 (0.39, 0.69)****
High school	0.84 (0.59, 1.21)	0.84 (0.58, 1.21)	0.77 (0.53, 1.12)	0.77 (0.53, 1.11)
Some college	1.03 (0.71, 1.51)	1.03 (0.71, 1.51)	0.95 (0.64, 1.40)	0.93 (0.63, 1.37)
College or more	**0.61 (0.39, 0.96)***	**0.62 (0.39, 0.98)***	**0.57 (0.35, 0.91)***	**0.56 (0.35, 0.90)***
Adjusted income	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)
Household with kids	**1.63 (1.17, 2.29)****	**1.62 (1.15, 2.27)****	**1.51 (1.07, 2.14)****	**1.51 (1.07, 2.14)****
Married	0.99 (0.73, 1.35)	0.98 (0.72, 1.34)	0.97 (0.70, 1.34)	0.96 (0.70, 1.33)
Access to car	1.22 (0.95, 1.58)	1.17 (0.91, 1.52)	1.17 (0.90, 1.53)	1.16 (0.89, 1.52)
Homewood	1.17 (0.91, 1.50)	1.21 (0.94, 1.55)	1.08 (0.84, 1.41)	1.00 (0.77, 1.33)

Note: Boldface indicates statistical significance.
* $p<0.05$, ** $p<0.01$.
SPI, standardized price index.

Table 5. Characteristics of low-price and high-price stores from audits

Price	Fruit/vegetable availability (%)	Junk food availability (%)	Dominant view healthy foods (%)	Dominant view junk foods (%)	Number of healthy food displays	Number of junk food displays
Low-price stores	18.3	7.0	14.0	67.0	7.7	43.9
High-price stores	20.8	7.7	71.0	33.0	20.2	37.2

traveled more than a mile to shop where healthy options were available. However, when the store prices were lower, the obesity rates of the shoppers were higher. These findings call into question the basic assumptions underlying the association between price and obesity.

Although distance and store prices were independently associated with obesity, only price remained significant when both variables were included. Similar to previous findings from Drewnowski and colleagues,[32] the inverse association between store prices and obesity suggests that residents who did their major food shopping at a low-price store have a higher chance of being obese. One plausible explanation for this association is that residents with low SES, and consequently higher rates of obesity, shop at low-price stores. However, the only SES measure found to distinguish between those who shopped at a low-price versus high-price store was car access.

Another plausible explanation for the inverse association between obesity and price level is that price level captures underlying differences in store environments such as differences in marketing of healthy and junk foods. Although prices for healthy foods are typically lower in supermarkets/wholesale clubs, so are prices for junk foods, which may lead to bulk purchasing and greater consumption.[40,41] Although availability of fruits/vegetables was similar across low-price and high-price stores (Table 5), fruits/vegetables often dominated the view from the main entrance at high-price stores, whereas junk foods were more visible in low-price stores. Low-price stores also had fewer displays to promote healthy foods compared to high-price stores. Taken together, it would appear that the high-price stores actively marketed healthy foods, whereas low-price stores actively marketed junk foods.

Low-income participants may also be willing to travel farther to a low-price store for better prices. Once inside a low-price store, shoppers may be influenced by displays and marketing of non-nutritious or junk foods.[42–45] The higher number of displays may motivate people to buy more quantity or in bulk, leading to a higher likelihood of obesity. One hypothesis is that low-income shoppers are particularly sensitive to price and to the methods in which different foods are displayed and promoted.[45–51] When a person is overloaded with information or has to make too many choices or trade-offs, processing is more likely to be non-cognitive—which is typically automatic, impulsive, or influenced by superficial characteristics. Supermarket environments tend to promote non-cognitive processing owing to the huge variety of inventory and massive stimulation in this setting.

Strengths and Limitations

This study benefits from the combination of objective store audits and survey reports to enable linking of store characteristics with an individual's health outcomes. A potential limitation is that most food desert residents have low SES; thus, these findings may not be generalizable to other populations. Another limitation of this paper is the focus on a major food shopping store, whereas people may shop at multiple stores. The store audits were conducted once whereas surveys were collected over 8 months; prices and displays may have changed over the survey period. Another limitation is the lack of data on purchases made by participants at the store where they shopped.

Conclusions

The findings of this study suggest that it may be important to offer better prices for healthy foods compared to junk foods and actively market healthy food choices simultaneously, while also enabling consumers to resist the influence of junk food marketing.

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