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The Neighborhood Food Environment, Food Stamp Program Participation, and Weight-Related Outcomes of Low-Income Women

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ABSTRACT

Purpose: Using a sample of low-income women, this paper examines whether the availability of food retail and food service establishments in a woman's neighborhood of residence (her "neighborhood food environment") was associated with food purchase decisions, daily energy intake or weight status. It also explores whether these associations differed for Food Stamp Program (FSP) participants compared to low-income nonparticipants.

Data: Restricted-access geocoded data from the 2007–2008 National Health and Nutrition Examination Survey was combined with 2007–2008 ZIP Code Business Patterns data measuring the availability of supermarkets, small grocery stores, convenience stores, fast food restaurants and full-service restaurants in a person's ZIP Code Tabulation Area of residence.

Methods: Ordinary Least Squares models of weight-related outcomes were estimated that included an indicator for household FSP participation in the previous year and either a set of separate neighborhood food establishment density variables or neighborhood food environment composite variables formed using factor analysis. All models controlled for a large set of additional individual and environment characteristics.

Results: In the models of weight-related outcomes that included separate neighborhood establishment density variables there were very few significant associations between the individual establishment density variables and the outcomes. However, the neighborhood establishment density variables were jointly significantly associated with many of the outcomes. In models including factors, higher neighborhood density of "small or quick" establishments was significantly associated with spending more of the family food budget at grocery stores, eating more fast food meals, less frequent major grocery shopping trips, higher BMI, and a higher likelihood of obesity. Higher neighborhood density of supermarkets and restaurants was associated with significantly fewer fast food meals per week, more frequent major grocery shopping trips, lower BMI, and a lower likelihood of obesity. However, the magnitudes of the estimated relationships suggest that the changes in behavior that would accompany

changes in the neighborhood food environment such as the opening of a new supermarket are likely to be quite small. Although FSP participants and low-income nonparticipants appear to respond similarly to neighborhood food environments, FSP participants lived in neighborhoods with a significantly higher mean density of “small or quick” establishments.

Keywords: Body Mass Index (BMI), Food Stamp Program, Women, Obesity, Neighborhood Food Environment

The Neighborhood Food Environment, Food Stamp Program Participation, and Weight-Related Outcomes of Low-Income Women

INTRODUCTION

A growing number of federal, state, local, and nonprofit initiatives have arisen to foster the development of supermarkets and establishments selling healthy food in low-income communities. These initiatives are typically framed by the assumptions that increasing the availability of these types of establishments will lead to an increased frequency of shopping at supermarkets and stores selling healthy food, lower-calorie, more-nutritious food choices, healthier weight status, and a lower incidence of weight-related comorbidities for neighborhood residents (see, for example, Centers for Disease Control 2012, Robert Wood Johnson Foundation 2011, and Institute of Medicine 2005a). However, the validity of these assumptions has not been established, as there is very little empirical research on the relationship between the neighborhood food environment and food shopping decisions; there is no previous research on the relationship between the neighborhood food environment and energy intake; and findings on the relationship between the neighborhood food environment and weight status are inconsistent across studies.

Using restricted-access data from the 2007–2008 National Health and Nutrition Examination Survey (NHANES) combined with 2007–2008 ZIP Code Business Patterns data, this paper attempts to fill in some of the gaps in the previous research by examining whether the neighborhood food environment in a low-income woman's neighborhood of residence was associated with decisions about where and how frequently to purchase food, daily energy intake, and weight status.[1] Multiple approaches were used to measure the neighborhood food environment. The models of weight-related outcomes included either a set of separate variables for each type of food retail and food service establishment or included neighborhood food environment composite variables derived from factor analysis of the

[1]For ease of explanation this set of outcomes is referred to as "weight-related" outcomes in the paper.

neighborhood establishment variables. The paper also explored whether these associations differed for Food Stamp Program (FSP) participants compared to low-income nonparticipants.[2]

BACKGROUND

Previous research on the relationship between the neighborhood food environment and the location and types of establishments where neighborhood residents purchase food is quite limited, but findings to date suggest that most people use a supermarket as their main source of groceries regardless of whether or not they have a supermarket in close proximity to their home. Two studies from the United Kingdom examined how shopping patterns changed in response to the opening of a large supermarket in a low-income area without a supermarket (one in Leeds and one in Glasgow). Wrigley et al. (2003) used an uncontrolled pre-post study design with respondents drawn from the neighborhoods around the new supermarket.[3] They found that 45 percent of respondents switched to the new supermarket as their main food source and that 76 percent of switchers had previously used a different supermarket as their main food shopping source. They found that there was not a significant change in daily fruit and vegetable consumption from before to after the supermarket opened in the full sample or among those who switched from another supermarket, but that those who switched from "limited-range/budget stores" significantly increased fruit and vegetable consumption by an average of 0.44 servings per day. Cummins et al. (2005) used a pre-post study design with respondents drawn from the intervention community as well as from a matched comparison community.[4] They found that only 30 percent of respondents in the intervention community switched to the new supermarket as their main food source and that around 50 percent of switchers had previously used a different supermarket as their main food shopping source. Cummins et al. found that there was not a significant change in fruit and vegetable consumption among the full sample or

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[2]The Food Stamp Program was renamed the Supplemental Nutrition Assistance Program (SNAP) in 2008. The program will be referred to as the Food Stamp Program in this paper since the data used in the empirical analyses are drawn primarily from the period before the name change.

[3]In Wrigley et al. "post" was 7 to 8 months after the supermarket opened.

[4]In Cummins et al. "post" was 10 months after the supermarket opened.

among switchers due to the opening of the supermarket. Ohls et al. (1999) and Cole (1997) found that many low-income individuals conducted their primary grocery shopping at a supermarket that was not the closest supermarket to their home. Previous research has not considered whether shopping patterns respond to the opening of a new supermarket in a higher-income area or in a neighborhood that already contained a supermarket or whether the neighborhood availability of other types of food establishments is associated with shopping patterns.

Previous research has not considered the relationship between measures of the neighborhood food environment and energy intake or energy availability. There is a fairly substantial body of research on the relationship between the neighborhood food environment and adult weight status (Currie et al. 2010, Ford and Dzewaltowski 2011, Gibson 2011, Jeffrey et al. 2006, Lopez 2007, Mehta and Chang 2008, Morland and Evenson 2009, Morland et al. 2006, Mobley et al. 2006, Wang et al. 2007, Zick et al. 2009). Findings on the relationship between neighborhood food environment measures and adult weight status have differed considerably across studies. For example, estimates of the relationship between neighborhood supermarket availability and adult BMI or obesity have ranged from negative and significant (Lopez 2007, Morland and Evenson 2009, Morland et al. 2006) to nonsignificant (Ford and Dzewaltowski 2011, Gibson 2011, Mobley et al. 2006, Zick et al. 2009) to positive and significant (Wang et al. 2007). The two previous studies that used a sample of low-income women found no relationship between BMI and measures of the neighborhood food environment (Mobley et al. 2006, Zick et al. 2009). The previous research on adults has not used factor analysis to combine neighborhood food environment variables into a smaller set of factors.

Previous research on the FSP has considered the types of establishments where Food Stamp (FS) recipients typically shop for food and the relationships between FSP participation and food expenditures, energy intake, and weight status. However, this research has not looked at whether these outcomes differ with the neighborhood food environments encountered by FSP participants. Research using data on Electronic Benefit Transfer (EBT) transaction patterns found that supermarkets and supercenters accounted for 64 percent of all EBT purchases and 84 percent of the dollar value of FSP benefits

redeemed (Castner and Henke 2011). Previous research has consistently found that FSP participants spend more on food than eligible nonparticipants and there is some evidence of a positive relationship between FSP participation and energy availability at the household level (see Fox et al. 2004 for a summary of previous research). Much of the previous research has found a positive and significant relationship between FSP participation and obesity or BMI for low-income women (Baum 2007, Chen 2005, Gibson 2003, Jilcott et al. 2011, Leung and Villamoor 2011, Meyerhoefer and Pylypchuk 2008, Townsend et al. 2001, Webb et al. 2008, Zargosky and Smith 2009). However, other studies have not found a significant relationship or have found a relationship that has declined over time (Fan 2010, Kaushal 2007, Ver Ploeg et al. 2007).

Restricted-access geocoded NHANES data provide the opportunity to look at whether a low-income woman's neighborhood food environment was related to her decisions about where and how frequently to purchase food, daily energy intake, and weight status. The main contribution of this paper is its use of a set of outcomes that deal with a variety of aspects of a person's food consumption decisions. This paper also adds to the literature through the use of factor analysis of neighborhood food environment variables and the consideration of whether the relationship between the neighborhood food environment and these outcomes differs with FSP participation.

METHODS

Sample

Data from the 2007–2008 NHANES on low-income non-pregnant women ages 20 to 65 years with a gross family income less than or equal to 130 percent of the federal poverty guideline appropriate for the family size (the gross income-eligibility threshold for FSP participation) were used in the empirical analyses. The NHANES collects data through interviews, physical examinations, and lab tests. The samples are designed to be nationally representative of the U.S. non-institutionalized civilian population. The NHANES uses a multistage probability sampling design with oversampling of African Americans, Hispanics, and persons age 60 years and older.

There were 696 low-income women between the ages of 20 and 65 surveyed in the 2007–2008 NHANES. Observations missing information on any of the explanatory variables described below or on any of the outcomes besides energy intake were excluded from the empirical analyses, as were observations with outlier values for neighborhood size and establishment density.[5] A sample of 558 low-income women was used in the analysis of all outcomes except energy intake. Women with missing or outlier values for energy intake were removed from this sample to create a sample of 484 low-income women that was used in the analysis of energy intake.[6]

Outcome Measures

The 2007–2008 NHANES collected information on a series of "consumer behaviors." NHANES respondents were asked how much money their family spent in the past month on food purchased from supermarkets and smaller grocery stores, on food purchased from other food retail establishments, and on carryout, delivered food, or eating out. The lead-in to these questions specifically prompted individuals to include purchases made with FS. Three food spending variables were created from these questions and used as outcomes: food spending in the past month per family member, the percentage of the monthly family food budget that was spent at grocery stores, and the percentage of the monthly family food budget that was allocated to eating out or on carryout or delivered food. Other food purchase behavior variables used as outcomes were the number of meals the respondent reported eating at fast food restaurants or pizza places in the past 7 days; an indicator variable for "infrequent shopping" equal to one for respondents who reported one or no major food shopping trips per month and equal to 0 otherwise; and usual travel time for a one-way trip to the grocery store most frequently used for food shopping.

[5]A low-income woman was excluded from the final sample if she resided in a ZIP Code Tabulation Area (ZCTA) with: land area >= 350 square miles, supermarket density per sq. mile >2, small grocery store density per sq. mile >10, or fast food establishment density per sq. mile >15. Twenty-one observations were missing establishment density information, 49 observations were outliers in establishment density, 27 observations were outliers in ZCTA size, 28 observations were missing weight information, and 13 observations were missing consumer behavior information.

[6]Please see footnote 9 for a discussion of the process of removing outliers in energy intake.

The 2007–2008 NHANES included two dietary intake interviews. The first interview was conducted in-person during the medical examination component (MEC) of the NHANES and the second interview was conducted by telephone 3 to 10 days following the MEC dietary interview. The dietary intake data are used by NHANES to estimate the energy intake from foods and beverages consumed during the 24-hour period prior to the interview (midnight to midnight). Daily estimated energy requirement (EER) is the usual intake level needed to maintain current weight in a healthy adult of a given age, gender, weight, height, and level of physical activity (Institute of Medicine 2005b). The average over the two interviews of the percentage of the daily EER consumed was used as an outcome.[7,8]

Weight and height were measured as part of the 2007–2008 NHANES medical exam. Body mass index (BMI) and obesity were also used as outcomes. BMI is defined as weight in kilograms divided by the square of height in meters. A woman was categorized as obese if her BMI was greater than or equal to 30 kg/m^2.

Explanatory Variables

Measurement of the Neighborhood Food Environment

A respondent's neighborhood of residence was defined as the respondent's ZIP Code Tabulation Area (ZCTA) of residence. Information on the location of residence of NHANES participants is not publicly available. However, information as detailed as a participant's census block of residence is

[7]Physical activity is not measured in sufficient detail in the NHANES to adjust an individual's EER by activity level. Therefore EER was calculated under the assumption that all individuals were "sedentary" and the regression for the average percentage of daily EER consumed included separate indicators for whether the respondent reported engaging in vigorous or moderate activity in the past month.

[8]Misreporting of food intake appears to be substantial in the 2007–2008 NHANES data given that for low-income women the mean percentage of the daily EER consumed without outliers removed was 90 percent. To reduce the influence of outliers, a daily energy intake observation was not included in the 2-day average of the percentage of EER consumed if it corresponded to a daily intake less than 50 percent of EER or more than 200 percent of EER. The regression models of the average percentage of daily EER consumed included controls for the number of days of energy intake included in the average, whether the respondent reported that consumption was "usual" on all of the days included in the average, and whether any of the days included in the average were weekend days.

available with the approval of the National Center for Health Statistics (NCHS) and with this information it is possible to determine an individual's ZCTA of residence. This project was approved by NCHS and work on this project was conducted at the New York Census Research Data Center–Baruch. All results presented in the paper have been cleared for release by the NCHS Research Data Center.

A respondent's neighborhood food environment was defined using data on food retail and food service establishments drawn from the year of the U.S. Census Bureau's ZIP Code Business Patterns Data corresponding to the NHANES survey year. Separate variables were created for the neighborhood density per square mile of each of the following establishment types: supermarkets, small grocery stores, convenience stores, limited-service restaurants, and full-service restaurants.

The U.S. Census Bureau's ZIP Code Business Patterns Data is released annually and contains counts of the number of establishments in each ZIP Code Area in the United States and Puerto Rico by North American Industry Classification System (NAICS) codes and within NAICS codes by employment size. NAICS codes were used to define grocery stores (code 445110), convenience stores (code 445120), limited-service restaurants (code 722211), and full-service restaurants (code 722110).[9] A grocery store was categorized as a "supermarket" if it had 50 or more employees and as a "small grocery store" if it had fewer than 50 employees (Gibson 2011, Lopez 2007, Moore and Diez Roux 2006).

A respondent was assigned the establishment counts of the 5-digit ZIP Code number that matched the respondent's 5-digit ZCTA number (Gibson 2011, Lopez 2007, Powell et al. 2007a, Powell et al. 2007b, Powell et al. 2006). ZCTAs are composed of census blocks and a census block is assigned the ZCTA number of the most frequently occurring ZIP Code of the addresses located in the census block. This introduces the possibility of measurement error in the establishment density variables because a ZCTA may contain addresses with additional ZIP Code numbers and addresses with the same ZIP Code

[9]Limited-service restaurants are establishments where patrons generally pay before eating (excluding snack and non-alcoholic beverage bars). This category is broader than, though roughly synonymous to, "fast-food" restaurants. For ease of exposition, limited-service restaurants will be referred to as "fast-food" restaurants for the remainder of the paper.

number as the ZCTA may be located beyond ZCTA boundaries. However, census blocks are fairly small on average, which reduces the likelihood of multiple ZIP Codes within a census block and within ZCTAs.[10]

Food Stamp Program Participation

The 2007–2008 NHANES asked respondents whether any members of the individual's household participated in the FSP in the previous 12 months. Individuals who replied yes were categorized as "household FSP participants." Alternate FSP participation variables were considered in sensitivity analyses and included whether the household participated in the FSP in the previous month and the amount of FS benefits received by the household in the previous month.

Other Explanatory Variables

Additional individual-level characteristics used as explanatory variables were the individual's family income-to-needs ratio, age, race/ethnicity (white non-Hispanic, black non-Hispanic, Hispanic, other race/ethnicity), educational attainment (less than high school, high school or GED, more than high school), family size, and marital status (married, unmarried). Additional neighborhood-level characteristics used as explanatory variables were the land area of the respondent's ZCTA of residence drawn from the 2000 Decennial Census and the poverty rate and population density in the respondent's census tract of residence drawn from the 2005–2009 American Community Survey 5-year estimates.

Statistical Analysis

Descriptive statistics were calculated for the sample of low-income women and within this sample by obesity status. Ordinary Least Squares (OLS) models of food purchase behaviors, daily energy intake, and weight status were estimated including either separate neighborhood food establishment

[10]For example, there are 192,568 census blocks in Wisconsin and average census block size is 0.28 square miles. Of these blocks, 792 had an area greater than 5 square miles.

density variables or neighborhood food environment factors. Principal factors factor analysis with promax oblique rotation of the neighborhood establishment density variables was conducted using a ZCTA-level data set that was composed of one observation for each ZCTAs that was represented in the sample of low-income women (n = 211). A scree plot and the interpretability of factors was used to choose the number of factors. ZCTA-level factor scores were calculated and merged with the NHANES data. It is assumed that choices about food purchase behaviors, daily energy intake, and weight status were made simultaneously. Given that the explanatory variables are identical for 6 of 9 outcomes and there are only minor differences in the explanatory variables for the 3 other outcomes, the results of seemingly unrelated regression models would not differ in a meaningful way from those using equation-by-equation OLS (Baum 2006).[11] Equation-by-equation OLS results are presented in this paper.

Four models were estimated for each weight-related outcome. **Model (1)** included only individual-level characteristics; **Model (2)** added separate neighborhood establishment density variables and other neighborhood characteristics to Model (1); **Model (3)** added neighborhood food environment factors and other neighborhood characteristics to Model (1); and **Model (4)** added interactions between each neighborhood food environment factor and household FS participation to Model (3).

Descriptive statistics and OLS regression models were estimated taking into account the complex design features of the NHANES (Centers for Disease Control 2005). The 2007–2008 NHANES examination weights were used for all analyses except for those involving the mean percentage of daily EER consumed. Analysis of this outcome used the 2007–2008 NHANES day one dietary intake weights. Taylor series linearization was used for variance estimation.

[11]In addition to the explanatory variables included in all models, the models of BMI and obesity also contained an age-squared variable. The model for the average percentage of daily EER consumed also included controls for whether the respondent reported engaging in moderate or vigorous physical activity in the past month and indicator variables for whether two days of energy intake were included in the average, whether the respondent reported that consumption was "usual" on all of the days included in the average, and whether any of the days included in the average were weekend days.

RESULTS

Descriptive Statistics

Compared to low-income women who were not obese, low-income obese women on average allocated a significantly higher percentage of their monthly food budget to grocery stores and a significantly lower percentage of their monthly food budget to eating out (Table 1). A significantly higher percentage of obese women grocery shopped infrequently. Obese women had a significantly lower mean travel time to the grocery store and consumed a significantly lower mean percentage of daily EER but had a significantly higher average daily kcal intake. There were no significant differences by obesity status in the mean neighborhood density per square mile of supermarkets, small grocery stores, and convenience stores. Compared to non-obese women, obese women lived in neighborhoods with a significantly lower mean density of fast food restaurants and full-service restaurants and a significantly higher mean poverty rate and mean percentage of residents who were FSP participants. However, obese women were significantly more likely to live in a neighborhood with at least one fast food restaurant. Compared to non-obese women, obese women were significantly more likely to live in a household that participated in the FSP in the previous year, be non-Hispanic Black or have less than a high school education, and were significantly less likely to be married or have engaged in moderate physical activity in the past month.

Regression Analyses with Separate Neighborhood Food Environment Variables

Table 2 shows the results of model (1) and model (2) for food purchase behaviors, daily energy intake, and weight status for the sample of low-income women. In model (1), FSP participation was negatively and significantly related to the percentage of the monthly food budget allocated to eating out and positively and significantly related to BMI and obesity. In model (2) the coefficient on FSP participation was not significantly related to obesity and while still significant the magnitude of the coefficient on FSP participation in the model of BMI was substantially smaller than in model (1).

Table 1: Description of the Weight-Related Outcomes, Personal Characteristics, Neighborhood Food Environment, and Other Neighborhood Characteristics of Low-Income Women in the 2007–2008 NHANES, All Estimates Weighted

	Low-Income Women	Non-Obese Low-Income Women	Obese Low-Income Women
Weight Related-Outcomes			
$ of food spending per month per family member, mean (SE)	166.6(7.8)	167.1(8.1)	165.9(13.4)
% of monthly food spending at grocery stores, mean (SE)	73.8(0.9)	**71.3(1.3)**	**77.1(1.5)**
% of monthly food spending allocated to eating out, mean (SE)	16.7(0.7)	**18.4(1.1)**	**14.3(0.6)**
Fast food meals consumed in past week, mean (SE)	1.5(0.1)	1.5(0.2)	1.5(0.2)
Infrequent grocery store shopper, % (SE)	24.0(3.4)	**20.0(3.6)**	**28.6(4.3)**
Minutes to main grocery store, mean (SE)	16.2(1.0)	**17.6(1.6)**	**14.4(0.7)**
Average daily kcal intake, mean (SE)	1900(50.8)	**1838(52.0)**	**1987(76.7)**
Average % of daily EER consumed, mean (SE)	94.9(2.3)	**98.7(2.5)**	**89.6(3.4)**
Body Mass Index, mean (SE)	30.0(0.4)	**24.2(0.3)**	**37.8(0.7)**
Obese, % (SE)	42.3(2.4)	0	100
Personal Characteristics			
HH FSP participation in past year, % (SE)	48.4(3.3)	**43.4(4.9)**	**55.3(2.9)**
$ of FS benefits HH rc'd in prev. month, mean (SE)	111.9(6.6)	95.6(13.7)	134.1(18.3)
Family income-to-needs ratio, mean (SE)	0.78(.02)	0.78(.02)	0.78(.03)
Family size, mean (SE)	3.4(0.1)	3.3(0.2)	3.5(0.1)
Married, % (SE)	29.3(2.3)	**33.4(3.7)**	**23.8(2.2)**
Age, mean y (SE)	38.2(1.3)	37.9(1.8)	38.7(1.3)
Non-Hispanic White, % (SE)	53.0(7.1)	54.9(5.7)	50.4(9.6)
Non-Hispanic Black, % (SE)	17.9(3.7)	**15.4(3.2)**	**21.3(5.1)**
Hispanic, % (SE)	24.2(5.9)	23.4(4.9)	25.3(7.9)
Other, % (SE)	4.9(1.3)	6.4(2.1)	3.0(1.0)
Education less than high school, % (SE)	38.1(3.8)	**33.9(4.9)**	**43.4(4.4)**
Any vigorous activity in past month, % (SE)	14.3(2.6)	16.7(3.2)	11.1(3.7)
Any moderate activity in past month, % (SE)	31.1(2.3)	**34.2(2.1)**	**26.8(3.8)**
ZCTA of Residence Neighborhood Food Retail Environment			
Supermarket density per sq. mile, mean (SE)	0.20(.05)	0.22(.05)	0.16(.05)
Small grocery store density per sq. mile, mean (SE)	0.72(.26)	0.73(.24)	0.72(.29)
Convenience store density per sq. mile, mean (SE)	0.40(.13)	0.41(.12)	0.39(.16)
One or more supermarket in ZCTA, % (SE)	74.3(4.4)	72.0(4.6)	77.4(5.4)
One or more small grocery store in ZCTA, % (SE)	89.8(2.8)	90.9(2.6)	88.2(4.2)
One or more convenience store in ZCTA, % (SE)	77.2(6.1)	77.8(5.3)	76.3(8.1)
ZCTA of Residence Neighborhood Food Service Environment			
Fast-food restaurant density per sq. mile, mean (SE)	2.0(0.4)	**2.2(0.5)**	**1.7(0.4)**
Full-service restaurant density per sq. mile, mean (SE)	2.0(0.5)	**2.4(0.5)**	**1.5(0.4)**
One or more fast-food restaurant in ZCTA, % (SE)	95.5(2.4)	**93.5(3.2)**	**98.2(1.4)**
One or more full-service restaurant in ZCTA, % (SE)	97.7(1.9)	97.3(2.0)	98.2(1.8)
Other Neighborhood Characteristics			
% HHs poor in census tract, mean (SE)	20.5(1.3)	**19.6(1.4)**	**21.8(1.7)**
% HHs received FS in census tract, mean (SE)	14.6(1.1)	**13.1(1.1)**	**16.7(1.3)**
Population dens per sq. m. in census tract, mean (SE)	501(181)	491(110)	514(141)

Notes: SE = standard error, EER = estimated energy requirement. FS = Food Stamps, FSP = Food Stamp Program, HH = household, ZCTA = ZIP Code Tabulation Area

Significant differences between obese and non-obese women are shown in bold and highlighted gray ($p<.10$).

Table 2: Coefficients (Standard Errors) from Ordinary Least Squares Models of Food Purchase Behaviors, Daily Energy Intake, and Weight-Status Outcomes, Low-Income Women, NHANES 2007–2008*

	Average Monthly Food Spending per Family Member	% of Monthly Food Spending at Grocery Stores	% of Monthly Food Spending Eating Out	# Fast Food Meals Consumed in Previous Week	Infrequent Grocery Shopper (1/0)	One-way Travel Time to Usual Grocery Store (min)	Average % of Daily EER Consumed	Body Mass Index	Obese (1/0)
Model (1)									
HH FSP participation in past year	-5.4(28.6)	3.0(2.5)	-5.5(1.8)**	.16(.26)	.04(.04)	2.2(1.7)	-3.4(4.5)	3.0(1.0)**	.09(.04)*
Family income-to-needs ratio	-20.1(25.9)	0.9(3.3)	2.9(2.1)	-.07(.25)	-.21(.08)**	-1.2(2.0)	10.6(5.8)*	2.5(1.0)**	.07(.07)
Model (2)									
HH FSP participation in past year	-6.5(26.1)	3.1(2.3)	-5.4(1.8)**	.01(.22)	.005(.04)	2.0(1.8)	-4.8(4.6)	2.2(1.0)**	.06(.05)
Family income-to-needs ratio	-21.2(27.4)	1.0(2.8)	2.8(2.1)	-.13(.23)	-.22(.07)**	-1.4(2.0)	9.7(6.2)	2.4(1.0)**	.06(.07)
Supermarket density per sq. mile	77.6(49.4)	-14.3(5.6)**	6.8(4.6)	-.25(.61)	-.18(.10)	-3.3(4.7)	10.8(11.1)	0.7(2.3)	-.07(.15)
Small grocery store density per sq. mile	5.1(8.1)	1.9(1.1)	0.1(0.7)	.17(.11)	.01(.01)	-0.5(0.9)	0.5(3.9)	0.8(0.5)	.01(.03)
Convenience store density per sq. mile	6.3(12.7)	0.5(2.2)	-0.8(1.5)	-.09(.22)	.08(.07)	0.4(2.2)	-3.1(5.2)	-0.7(1.2)	.03(.06)
Fast-food restaurant density per sq. mile	-7.3(7.6)	0.5(0.5)	-0.7(0.4)	-.08(.08)	-.02(.02)	1.8(0.8)**	0.6(1.8)	-0.5(0.3)	-.02(.02)
Full-service restaurant density per sq. mile	-0.5(4.0)	-0.1(0.4)	0.4(0.2)*	-.04(.03)	-.01(.007)*	-1.0(0.6)*	-1.9(1.1)	-0.3(0.2)	-.02(.01)
Model (3)									
HH FSP participation in past year	-2.2(27.6)	2.6(2.2)	-5.2(1.7)**	.03(.23)	.002(.05)	2.2(1.7)	-4.1(5.0)	2.5(1.1)**	.06(.05)
Family income-to-needs ratio	-20.8(27.5)	0.9(2.9)	2.8(2.0)	-.13(.23)	-.22(.07)**	-1.2(1.9)	9.9(6.4)	2.4(1.0)**	.06(.07)
Supermarket and restaurant density factor	11.3(10.0)	-0.7(1.6)	1.0(1.1)	-.26(.10)**	-.08(.04)*	0.7(1.4)	-2.2(5.9)	-1.4(0.5)**	-.11(.03)**
Small or quick establishment density factor	2.5(9.2)	4.0(1.2)**	-1.4(1.2)	.28(.14)*	.11(.03)**	0.9(1.9)	0.3(2.3)	1.3(0.5)**	.08(.03)**

Notes: All estimates weighted, EER = estimated energy requirement, FSP = Food Stamp Program, HH = household, min = minutes
Neighborhood food environment factors were derived from factor analysis shown in Table 3.
All models included controls for family size, marital status, age, race/ethnicity and educational attainment. Models (2) and (3) also included the land area of the respondent's ZIP Code Tabulation Area of residence and the poverty rate and population density in the respondent's census tract of residence. Models for the average % of daily EER consumed also included controls for whether the respondent reported engaging in moderate or vigorous physical activity in the past month and indicator variables for whether two days of energy intake were included in the average, whether the respondent reported that consumption was "usual" on all of the days included in the average, and whether any of the days included in the average were weekend days.
** = significant at p<.05; * = significant at p<.10

In model (2) the only significant relationships between the neighborhood establishment density variables and the weight-related outcomes were that supermarket density was negatively and significantly related to the percentage of the monthly food budget allocated to grocery stores; fast food restaurant density was positively and significantly related to travel time to the grocery store; and full-service restaurant density was positively and significantly related to the percentage of the monthly food budget allocated to eating out and negatively and significantly related to infrequent grocery shopping and travel time to the grocery store. However, the neighborhood establishment density variables were jointly significantly associated with the percentage of the monthly food budget allocated to grocery stores, the number of fast food meals consumed in the past week, the frequency of major grocery shopping trips, BMI, and obesity.

Exploratory Factor Analysis & Regression Analyses with Neighborhood Food Environment Factors

The neighborhood food environment density variables were highly correlated, with correlations between variables ranging from 0.46 for the correlation between small grocery store density and full-service restaurant density, to 0.82 for the correlation between supermarket density and fast food restaurant density. Two factors were retained in the exploratory factor analysis. The eigenvalue on the first factor was 3.25 and the eigenvalue on the second factor was 0.28. Although the eigenvalue on the second factor was less than 1.0, this factor was easily interpretable and was the only factor to load highly on small grocery store density and convenience store density. Factor loadings (Table 3) were used to label the two factors as supermarket and restaurant density (related to higher density of supermarkets, fast food restaurants, and full-service restaurants) and “small or quick” establishment density (related to higher density of small grocery stores, convenience stores, and fast food restaurants). The density of fast food restaurants had a factor loading greater than .30 for both factors.

In model (3) the supermarket and restaurant density factor was negatively and significantly related to the number of fast food meals consumed in the past week, infrequent major grocery shopping trips, BMI, and obesity (Table 2). The small or quick establishment density factor was positively and

Table 3: Factor Loadings and Scoring Coefficients Relating Neighborhood Establishment Density Variables to Two Neighborhood Establishment Density Composite Factors

	Supermarket and Restaurant Density Factor	Small or Quick Establishment Density Factor
Factor Loadings		
Supermarket density per sq. mile	**0.783**	0.083
Small grocery store density per sq. mile	0.089	**0.763**
Convenience store density per sq. mile	0.199	**0.637**
Fast-food restaurant density per sq. mile	**0.697**	**0.329**
Full-service restaurant density per sq. mile	**0.769**	0.034
Scoring Coefficients		
Supermarket density per sq. mile	0.22	-0.05
Small grocery store density per sq. mile	-0.08	0.38
Convenience store density per sq. mile	0.03	0.28
Fast-food restaurant density per sq. mile	0.64	0.42
Full-service restaurant density per sq. mile	0.18	-0.05

Notes: Principal factoring factor analysis with promax oblique rotation of the neighborhood establishment density variables was conducted using a ZCTA-level data set that was comprised of one observation for each ZCTAs that was represented in the sample of low-income women (n = 211). Factor loadings >0.3 are shown in bold to facilitate interpretation of the factors.

significantly related to these outcomes as well as the percentage of the monthly food budget allocated to grocery stores.

Model (4) included the interaction of the factors and household FSP participation. The only significant interaction between FSP participation and the factors was the interaction between FSP participation and small or quick establishment density in the model of the percentage of the monthly food budget allocated to eating out (coefficient: 5.8, p=.033). For this outcome the coefficient on the small or quick establishment density factor was substantially larger than in was in model (3) and it was significant (coefficient: -4.2, p=.026). The results of model (4) are not shown.

Sensitivity Tests

Model (3) was re-estimated using alternate measures of FSP participation (FSP participation in the past month or amount of FS benefits received in the past month). The magnitude and significance of the coefficients on the neighborhood food environment factors in these models were similar to those presented in Table 2. In further sensitivity tests, indicator variables for having engaged in moderate or vigorous physical activity in the past month, proxies for the neighborhood physical activity environment, were added to model (3) of BMI and obesity. The coefficients on and significance of the FSP participation variable and the neighborhood food environment factors were essentially the same as those presented in Table 2.

DISCUSSION

In the models of weight-related outcomes that included separate neighborhood establishment density variables there were very few significant associations between the individual establishment density variables and the outcomes. However, the neighborhood establishment density variables were jointly significantly associated with many of the outcomes. Highly correlated neighborhood food environment variables may explain why these variables have often been insignificant in previous studies and why there have been inconsistent findings across studies. Previous research on adults has not used neighborhood food environment composites developed using factor analysis.

In models including neighborhood food environment factors, higher neighborhood density of "small or quick" establishments was significantly associated with spending more of the family food budget at grocery stores, eating more fast food meals, less frequent major grocery shopping trips, higher BMI, and a higher likelihood of obesity. The findings suggest that "small or quick" establishments are used more frequently as their density increases, which results in more fast food meals and less frequent major grocery shopping trips, and that these behavior changes are accompanied by increased BMI and an increased likelihood of obesity. Given that prices at small grocery stores are higher on average than those at supermarkets, more frequent trips to smaller grocery stores may explain why the percentage of the food budget spent at grocery stores is positively related to this factor (Ver Ploeg et al. 2009). "Small or quick" establishment density was not associated with the average percentage of daily EER consumed. However, as discussed earlier, food intake in the 2007–2008 NHANES appears to be reported with substantial error. BMI and obesity status were constructed from measured weight and height.

For low-income women, higher neighborhood density of supermarkets and restaurants was associated with significantly fewer fast food meals per week, more frequent major grocery shopping trips, lower BMI, and a lower likelihood of obesity. These findings suggest that living in a neighborhood with more of these types of establishments results in substitution towards more frequent shopping at supermarkets and away from fast food, and that these behavior changes are accompanied by decreased BMI and a decreased likelihood of obesity.

The inclusion of the neighborhood establishment density variables in the models of weight-related outcomes reduced the magnitude of the coefficients on household FSP participation, indicating that coefficients on FSP participation may be biased in models that exclude contextual variables. After the inclusion of the contextual variables, FSP participation remained negatively and significantly related to the percentage of the monthly food budget allocated to eating out and positively and significantly related to BMI but it was no longer significantly related to obesity. The addition of interactions between FSP participation and the neighborhood food environment factors to the models resulted in nonsignificant coefficients on the interactions in all of the models except for the percentage of the monthly food budget

allocated to eating out. Therefore it appears that FSP participants and low-income nonparticipants generally respond similarly to a given neighborhood food environment. However, FSP participants lived in neighborhoods with a significantly higher mean density of "small or quick" establishments than low-income nonparticipants, which results in both a higher predicted BMI and likelihood of obesity for FSP participants relative to low-income nonparticipants.

Although the models estimated in this paper included detailed measures of the neighborhood food environment and a large set of demographic, socioeconomic, and environment characteristics, it is possible that the estimates of the relationships between the neighborhood food environment variables, FSP participation, and the weight-related outcomes may be biased as a result of reverse causality or omitted variable bias. Low-income women with a higher demand for calories may be more likely to participate in the FSP and choose a neighborhood that offers a larger density of fast food establishments. Omitted variable bias is a possibility because the models do not include measures of long-term FSP participation, long-term neighborhood food environment exposures or measures of the food environments encountered outside a person's neighborhood of residence (Gibson 2011, Gibson 2003). NHANES does not collect the information necessary to construct these types of variables. It is therefore important to emphasize that the results in this paper should not be interpreted as causal.

The results in this paper provide strong support for the argument that the neighborhood food environment is associated with the food purchase behaviors and weight-status outcomes of low-income women. Determining whether the coefficients on the neighborhood food environment factors in the models of weight-related outcomes imply large or small behavior changes with changes in the neighborhood food environment requires the additional step of looking at the scoring coefficients from the factor analysis. Supermarket density is the focus of the subsequent discussion since increasing the availability of supermarkets for low-income individuals has been of particular policy interest. Supermarket density had a scoring coefficient of 0.22 in the regression of the supermarket and restaurant density factor on the neighborhood food establishment density variables. Therefore increasing supermarket density by 1 standard deviation, an increase of 0.31 supermarkets per square mile, would

result in a 0.22 unit increase in the value of the supermarket and restaurant density factor. This is turn would be predicted to result in a reduction of 0.05 fast food meals per week, a 1.8 percentage point drop in the probability of shopping infrequently, a 0.31 unit reduction in BMI, and a 2.4 percentage point drop in the probability of obesity. The average weighted ZCTA size in the sample is 55 square miles. Creating a one standard deviation increase in supermarket density in a ZCTA of this size would require an additional 17 supermarkets. Consistent with the findings of Cummins et al. (2005) and Wrigley et al. (2003), this suggests that the average behavioral response of ZCTA residents from the opening of one supermarket in the ZCTA is likely to be very small.

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