Title: Food retail provisioning, dietary behavior and weight outcomes in North Carolina

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Abstract: Aspects of the built environment may be contributing to the upward trend in obesity through constrained availability and affordability of healthful foods. The neighborhood food environment factors such as the availability of food retail stores is increasingly being recognized as playing an important role in health behaviors and health outcomes. We examine the local availability of retail food stores and their influence on the risk of obesity in North Carolina. Data on food stores were linked through county codes to individual data from the BRFSS data and multilevel modeling was employed to assess their associations with BMI. In regressions that included fruit and vegetable servings, and food store types as explanatory variables, our result show that BMI decreased with availability of supermarkets, and consumption of more servings of fruits and vegetables. In contrast increased availability of gas and convenience type food store outlets was associated with increased BMI.

Introduction

Obesity has increased dramatically in the US over the past two decades. In North Carolina the adult obesity rate has doubled from 13% in the 1990s to 24.7% in 2006 (Trust for America's, 2007). Several factors may contribute to obesity including, environmental, psychological, demographic, and social factors. The neighborhood environment is increasingly being recognized as playing an important role in health behaviors and health outcomes. Aspects of the built environment may be contributing to the upward trend in obesity through constrained availability and affordability of healthful foods. Studies have demonstrated disparities in provisioning of food retail outlets by area socioeconomic and demographic characteristics, e.g., (Power et. al., 2006). Other studies have found associations between access to certain type of food stores and dietary intake e.g., the Atherosclerosis Risk in Communities Study (ARIC) shows a positive direct relationship between living in a census tract with at least one supermarket and meeting the USDA recommendation of consuming at least five or more servings of fruit and vegetables (Morland et. al., 2002). Few studies, however, have explored the link between retail availability, dietary behavior and weight outcomes. Recent U.S. studies in this line of inquiry include Sturm and Datar (2005) and Powell et. al. (2007) for adolescents, and for adult BMI, Morland et. al. (2006), and Morland and Evenson (2009).

Whereas these studies differ in scope and methodologies, they have common findings that associate differential access to food store outlet types to, reduced risk of obesity. Other studies mainly from outside the US, though, have found a lack of association between the local food environment and weight outcomes. This current study builds on the evidence base regarding the association between contextual factors and health outcome by focusing on the role of the food environment in access to healthy food. We examine access to retail food stores and the influence of different types of food stores on the risk of obesity in North Carolina. With a few exceptions most previous studies suffer from lack of completeness of the models used, in terms of measuring and adjusting comprehensively for intervening variables both at the individual and area levels (Holsteen J., 2009). Examination of the determinants of obesity from multiple levels have been advocated by other researchers (Deiz Roux, 2001; Kylie Ball et al. 2006), in particular, for the use of multilevel models to accommodate the effects of both individual and contextual level factors. While examination of determinants of obesity in a comprehensively complete manner may not be possible, broadening the array of predicted factors to include individual, social and environmental elements may provide further insights into the obesity conundrum (Ball K, 2006). In this study we employ multilevel modeling approaches to investigate a broader range of factors influences on obesity. However, the main focus our study is to shed further light on the question: does the availability and distribution of different types of food retail outlets in the local food environment influence health outcomes independently of their indirect effect through the level of healthy foods consumption. The local food environment is broadly defined to be geographically bounded by county demarcations in the state of North Carolina (Larson et al., 2009).

The food environment in North Carolina has in recent years, undergone rapid changes that have implications for access to food. The economic downturn in the late 1990s, in part due to the rapid erosion in the textile manufacturing base of the state economy, as well as the loss of the tobacco industry, among other factors, have led to restructurings that have affected rural counties adversely in terms of lost jobs and incomes, thereby impairing their food security status. In addition to financial constraints faced by consumers, the geographical access to food stores has deteriorated given the outright store closings, as well as consolidations that have taken place. In

particular, large food store chains have withdrawn from entire regions of the state, as well as from parts of local communities. In North Carolina the numbers of supermarkets and other grocery stores (except convenience stores) have consistently shown a declining trend. In 2000 there were 2,106 supermarkets and other grocery stores, by 2006 this had declined to 1884 stores statewide. The current economic downturn is likely to continue the downward slide in numbers of food outlets. This trend has likely impacted some food stores noted as points of easier access for healthful foods. For example, large stores have been associated with easy availability of fruits and vegetables. The impact of the loss of supermarkets is more likely to be felt in rural counties as the numbers of establishments are relatively very low in the rural counties. The results of 2006 study (Blanchard and Lyson) indicate that five counties, all in the North eastern part of the state, lack convenient access to a supermarket or supercenter. These counties include Northampton, Gates, Bertie, Tyrell, and Hyde.

Methods

Data for this study were obtained from two sources; 2006 U. S. Census Bureau, County Business Pattern, and Behavioral Risk Factor Surveillance Survey (BRFSS). Information on the number of food stores outlets by type according to North American Industry Classification System (NAICS) (supermarkets, convenience stores and convenience stores with gas stations) for North Carolina were obtained from the County Business Pattern of the U.S. Census Bureau. Individual data including Body Mass Index (BMI), fruit and vegetable consumption, and socioeconomic information- age, income, education, employment, race, gender and physical activity were obtained from the BRFSS. The BRFSS is a continuous annual telephone survey of adults, and conducted by state health departments in collaboration with the Centers for Disease Control. Data on food stores were linked through county codes to individual data from the BRFSS data.

Outcome Variable

The primary dependent variable was individual BMI, defined as weight in kilograms divided by the square of height in meters. BMI was calculated from self-reported weight and height and is therefore subject to the well-known biases of self-report data (Palta et al., 1982; Stunkard and Albaum,1981; Kuczmarski et al., 2001).

Explanatory Variables

Fruit and vegetable consumption

Fruit and vegetable consumption per day was calculated as the sum of respondent's consumptions per day of fruit juice, fruit, green salad, potato, carrot and vegetable (BRFSS 06 codebook). In the BRFSS survey fruit, and vegetable intakes were assessed by asking "Not counting juices how often do you eat fruit? Similarly for vegetables, "Not counting potatoes, carrots or salad how many servings of vegetables do you eat? (Example: A serving of vegetable at both lunch and dinner would be two servings)". For fruit juices, the question was asked: "How often do you drink fruit juices such as orange, grapefruit or tomato?" Consumption of salads, potatoes, and carrots were assessed by the following questions: "How often do you eat green salad?"; "How often do you eat potatoes, not counting french fries, fried potatoes, or potato chips?" and "How often do you eat carrots?"

Food Environment

A measure of food store availability at the county level was computed as total number of four food store types (Supermarket and larger grocery stores, smaller grocery stores, convenience stores and convenience stores with gas stations) per 10,000 of the population. The category supermarkets and larger grocery stores was based on NAICS code 445110, excluding stores with less than 50 employees. Smaller grocery store category is based on NAICS code 445110, excluding stores with 50 or more employees. Store types classified as convenience stores, and gasoline stations with convenience stores correspond to NAICS codes 44512 and 44711 respectively. Table 1 shows that the mean per 10,000 capita supermarkets outlets was 0.6. The store density per 10,000 capita for smaller grocery store, convenience stores, and gasoline stations with convenience stores were 1.43, .89, and 4.68 respectively.

Socioeconomic Variables

Socioeconomic variables include individual level variables comprising age (mean age 54.4 years), race (white 77.8%, black 14%, Hispanic 4% and other 4.2%), education (less than high school, graduated high school, attended college or technical school, and graduated from college), income (less than $15000, $15,000 to less than $25,000, $25,000 to less than $35,000, $35,000

to less than $50,000, and $50,000 or more), and binary gender, and employment status (employed and not employed) variables (Table 1). An indicator of rurality and urbanization of the county was derived from USDA Beal Rural Urban Continuum codes (USDA, ERS (2003)). Table 1 shows that 67.7 percent of the sample resided in metro counties, 29.1 percent in urban and only 3.2 percent in rural counties. Furthermore, we include a measure of overall physical activity levels as explanatory variable in BMI models. Only 10.8 per cent respondents met the recommendation for moderate and vigorous activity, 42 per cent had insufficient activity to meet moderate and vigorous recommendations and 16.8 per cent had no physical activity.

Model

The data for this study were obtained at two levels: individual level (survey data on, BMI, fruit and vegetable consumption, and socioeconomic variables) and county level (food store density). Thus we adopted multilevel modeling estimation approaches. Multilevel modeling allows an examination of both individual and contextual level variables on an outcome (Gelman A. Hill, 2007). We fitted two level linear regressions, with a random intercept for each county, in the multilevel model in SPSS 17, using the REML estimation method. For parsimony of the models, in general, we omit cross level interaction terms between individual level and environmental variables. We however include cross level interaction term between fruit and vegetable consumption and food store type to test whether there is an interaction effect, independent of their individual separate effects. A stepwise approach is taken, where we estimate a number of models designed to assess the influence of the food environment factors separately, and subsequently, correcting for the influence of dietary behavior, physical activity and individual level variables on obesity.

We first estimate an empty model (model 1) that includes only the intercept term which is allowed to vary across counties (random intercept model). The estimated unconditional intraclass correlation (ICC) from this model indicates the proportion of the variation in BMI due to between county variations. The remaining variation is between individuals. Model 2 is estimated by adding county level food environment variables-food store types, supermarket, grocery stores, convenience stores and gas and convenience stores. Next in model 3, we added individual level fruit and vegetable consumption to model 2 and in Model 4, we included interaction terms

between food store types and individual fruit and vegetable consumption. Model 5 was estimated by adding individual level physical activities variables to model 4. The full model (model 6) was estimated by adding individual level socioeconomic and demographic variables to model 4. The ICC was calculated for each model. Furthermore, changes in the β coefficients for the food environment variables, as a result of the sequential addition of fruit and vegetable consumption, physical activity, and individual socioeconomic and demographic variables were observed. The results of the sequential analyses are shown in table 2.

These models can be summarized as follows.

Empty model: $K_{ij} = \beta_{oj} + \varepsilon_{ij}$ ---------- *(1)*

$K_{ij} = \beta_{oj} + \beta_{o1}ST_j + \varepsilon_{ij}$ ---------- *(2)*

$K_{ij} = \beta_{oj} + \beta_{o1}ST_j + \beta_{o2}FV_{ij} + \varepsilon_{ij}$ ---------- *(3)*

$K_{ij} = \beta_{oj} + \beta_{o1}ST_j + \beta_{o2}FV_{ij} + \beta_{o3}ST_jFV_{ij} + \varepsilon_{ij}$ ---------- *(4)*

$K_{ij} = \beta_{oj} + \beta_{o1}ST_j + \beta_{o2}FV_{ij} + \beta_{o3}ST_jFV_{ij} + \beta_{o4}PA_{ij} + \varepsilon_{ij}$ ---------- *(5)*

$K_{ij} = \beta_{oj} + \beta_{o1}ST_j + \beta_{o2}FV_{ij} + \beta_{o4}FA_{ij} + \beta_{o5}NV_{ij} + \varepsilon_{ij}$ ---------- *(6)*

The intra-class correlation ICC: $\Psi = \frac{\tau 00}{\tau 00 + \delta^2}$

$\beta_{oj} = \gamma_{00} + \omega_{0j}$

Where:

β_{oj} is a county specific mean, composed of γ_{00} and ω_{0j};

γ_{00} is the grand mean of the outcome in the population;

ω_{0j} is a county specific random deviation from the grand mean, assumed t be distributed N(0, τ_{00});

τ_{00} is the within county variance;

K_{ij} is the BMI measure for individual i in county j;

ε_{ij} is an individual specific random error, assumed to be distributed N(0, δ^2);

δ^2 is the between county variance;

ST_j represents a vector of area food store variables in county j;

FV_{ij} represents a vector of individual's fruit and vegetable consumption in county j;

ST_jFV_{ij} represents interaction between food stores and fruit and vegetable consumption;
PA_{ij} represents a vector of individual level physical activities in county j;
NV_{ij} represents a vector of individual level socioeconomic and demographic variables.

Results

Results from estimation of the empty model shows that a great deal of the variability in BMI is due to individual level variables, however, a significant but small proportion of the variability is also accounted for at the area food environment level. Results from model 2, where only area level variables represented by the different food store type availability is modeled shows that, supermarket and convenience and gas store availability are statistically significant predictors of BMI. A unit increase in supermarket availability per 10,000 persons in a county, results in 2 units decrease in obesity rate. On the other hand, the obesity rate increases by 0.23 units as the density of convenience and gas stores increases by one unit in a county. The availability of smaller size grocery stores, and convenience stores was not statistically significantly associated with obesity. Adjusting the model 2 in subsequent estimations first, by including fruit and vegetable consumption, and physical activity level of individuals and second including individual level socioeconomic and demographic variables, did not change the direction of association for availability of supermarkets and convenience and gas stores as reported above. However, the stability of the parameter estimates for supermarkets and convenience and gas stores was affected, where in both cases reduction in the magnitudes of these parameters occurred. The implication of this instability of the parameter estimates is that the correlation of obesity with the contextual variables is in part due to the individual level variables. Indeed, as the model is adjusted sequentially for the individual level variables, the magnitude of the parameter estimate for supermarket availability is cut in half from 2.20 to 1.10.

The drastic drop in the parameter estimate for store availability as we controlled for individual level variables is a reflection of the important role these variables play in obesity rates. A large part of the variation in BMI is explained by the individual level factors including, physical activity levels, ethnicity, educational attainment and employment status. The results of model 5 show a strong negative gradient as the level of physical activity increased with BMI. Being black is positively statistically significantly related to obesity. Education levels influenced obesity

levels. Compared to individuals with college level education, individuals with lower levels of education exhibited a positive association with BMI. Being employed had a negative influence on BMI as well. Income was not statistically significant in models that it was included in. The association of supermarket and convenience and gas store with BMI vanishes in models that included interaction of fruit and vegetable consumption with food store availability. We lose the independent statistical significance of supermarket, and gas and convenience stores variables, and only the cross level interaction between fruit and vegetable consumption and convenience and gas stores was statistically significant.

Discussion

In regressions that included fruit and vegetable servings, and food store types separately as explanatory variables, our result show that BMI decreased with availability of supermarkets, and consumption of more servings of fruits and vegetables. In contrast increased availability of gas and convenience type food store outlets was associated with increased BMI. These findings of association of the risk of obesity with differential availability to food stores types and obesity are consistent with Powell's findings that increased availability of supermarkets was associated with lower adolescent BMI and a reverse result with convenience stores. Furthermore, our result parallels the facts on the ground in the state. The availability of supermarkets in rural counties is low or nonexistent for miles in between. Counties in the North eastern parts of the state are more likely to have fewer than five food stores with over 50 employees. Overweight and obesity is highest in North eastern counties in North Carolina and exceed 65% (BRFSS 06). Thus the results from this study seem to reinforce the notion that the existence of 'food deserts' in certain counties may be exacerbating the obesity problem. Community and public policy interventions directed at increasing the availability of food outlets conducive to increasing access to fruits and vegetables maybe necessary to attenuate the high rates of overweight and obesity. Improving the availability of supermarkets, and farmers markets may enhance access to healthy food choices.

Table 1: Descriptive Statistics of Individual BMI, Fruit and Vegetable Consumption, Socio-Demographic and Food Environment Variables in North Carolina.

Variables	Mean or Percentage	Standard Error for Continuous Variable
Body Mass Index	27.76	6.03
Fruits and vegetable serving per a day	3.76	2.07
Socio-Demographic Characteristics		
Mean Age -years	54.4	16.63
Gender		
Men	36%	
Women	64%	
Race		
White	77.80%	
Black	14%	
Hispanics	4%	
Others	4.20%	
Income		
Less than $15,000	11.90%	
$15,000 - >$25,000	18.60%	
$25,000->$35,000	12.70%	
$35,000 - >$50,000	16.60%	
$50,000 and more	40.20%	
Education		
Did not graduate High School	14%	
Graduated High School	29.80%	
Attended College/Tech. Sch.	25.90%	
Graduated College/Tech. Sch.	30.30%	
Employment Status		
Employed	49.90%	
Not Employed	50.10%	
Urbanization		
Metro	67.70%	
Urban	29.10%	
Rural	3.20%	
Mean number of Food Store Type per 10,000 capita		
Supermarkets and Larger stores (50 or more employees)	0.6	0.22
Grocery stores (Less than 50 employees)	1.43	0.49
Convenience Stores	0.87	0.42
Gas Stations and Convenience Stores	4.76	1.25

Table 2: Estimated Effects of Food Store Types, Dietary Behavior and Socio-Demographic Variables on BMI in North Carolina.

Variables	Model 1 Estimates	Model 2 Estimates	Model 3 Estimates		Model 4 Estimates		Model 5 Estimates		Model 6 Estimates	
Intercept	27.92	28.21	28.91		30.04		31.18		28.06	
Supermarkets and Larger stores (50 or more employees)		-1.95	-1.84	***	-2.20	***	-1.93	**	-1.10	***
Grocery stores (Less than 50 employees)		-0.19	-0.17		0.03		0.10		-0.13	
Convenience Stores		0.23	0.22	**	-0.07		-0.11		0.19	**
Gas Stations and Convenience Stores		-0.01	-0.01		0.12		0.04		-0.25	
Fruit and Vegetable servings per day			-0.19	***	-0.48	***	-0.38	**	-0.06	*
*Supermarkets and Larger stores *Fruit and Vegetable*					0.09		0.06			
*Grocery stores * Fruit and Vegetable*					-0.05		-0.06			
*Convenience Stores * Fruit and Vegetable*					0.07	**	0.07	**		
*Gas Stations and Convenience * Fruit and Vegetable*					-0.04		-0.02			
Physical Activity										
Moderate and Vigorous							-2.83	***	-2.55	***
Vigorous							-2.42	***	-2.27	***
Moderate							-1.99	***	-1.72	***
Insufficient Moderate and Vigorous							-1.12	***	-0.98	***
Race_Other									0.21	
Hispanics									-0.35	
Black									2.58	***
White									0.00	
Urbanization Metro									0.61	
Urban									0.71	
Male									0.44	***
Employed									-0.47	***
Did not graduate High School									0.72	***
Graduated High School									0.71	***
Attended College/Tech. Sch.									0.76	***
Less than $15,000									0.39	
$15,000 - >$25,000									0.17	
$25,000->$35,000									-0.09	
$35,000 - >$50,000									0.19	
ICC	0.01	0.004	0.003		0.004		0.003		0.001	
N	13599	13599	13599		13599		13599		13599	

Note: asterisk indicates estimates significance level-- *** p < .001, ** p<.05, * p<.10.
Reference categories for categorical variables: No Moderate or Vigorous Physical Activity, Whites, Rural, Female, Not Employed, Graduated from College/Tech. School, $50,000 and more

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