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Examining the Impact of Food Environment Changes on County-level Obesity Prevalence in the Appalachian Region

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ABSTRACT

The aim of the present study was to understand the impact of changes in the food environment on county-level obesity prevalence in the Appalachian Region. We examined the food environment in 412 counties across the Appalachian Region using data from the Behavioral Risk Factor Surveillance System, the American Community Survey, and the Food Environment Atlas. We found there was an overall decrease of per capita food stores from 2007 to 2011 in this region. There was also a significant relationship between the decrease of grocery stores per capita from 2007 to 2011 and the increase of county-level obesity in 2012. Our findings may provide insights into regional obesity disparities and county-level health policy strategies in the Appalachian region.

Keywords: Obesity, Food Environment, Appalachia, Rural Community, Public Health

INTRODUCTION

Obesity continues to be a critical health issue in the US. One-third of American adults are obese (Centers for Disease Control and Prevention, 2014), a rate that jumps to 40% in rural areas (Befort, Nazir, & Perri, 2012). Obesity generates a series of negative physical consequences, including diabetes (Mokdad et al., 2003), high cholesterol (Dietz, 1998), and high blood pressure (Boyd, Koenigsberg, Falkner, Gidding, & Hassink, 2005). From 1998 to 2008, obesity-related medical expenditures in the US increased by 68.5 billion dollars (Black, 2014). This epidemic has been especially severe in the Appalachian region, with many counties in the North Central, Central, and Southern sub-regions of Appalachia consistently exhibiting some of the nation's highest rates of obesity (Wang, Slawson, Relyea, Southerland, & Wang, 2014).

Although prior studies have identified the built-food environment as one of the crucial factors affecting the obesity epidemic, little research has examined changes in the food environment and their influence on obesity prevalence at the county level within the Appalachian region (Drewnowski & Specter, 2004; Lake & Townshend, 2006; Walker, Keane, & Burke,

2010). The association between the food environment and obesity prevalence is especially important for this socio-economically disadvantaged region, where the increase or decrease in food-store availability may impact dietary habits by providing for or restricting access to certain types of food (Lopez-Zetina, Lee, & Friis, 2006). In this study, we examine the changes in the food environment and its influence on county-level obesity prevalence in the Appalachian region.

Rural-Urban Disparities in Obesity

Approximately 60 million people, or 19.3% of the US population, are currently living in rural areas (The U.S. Census Bureau, 2017a). Over the past several decades, rural residents have experienced poorer health outcomes compared to that of their urban counterparts, including higher rates of diabetes and coronary heart disease (O'Connor & Wellenius, 2012), lower life expectancy (Singh & Siahpush, 2014), and higher rates of mortality (Cossman, James, Cosby, & Cossman, 2010). These disparities may, at least partially, be explained by the rural-urban differences in obesity (Befort et al., 2012). Rural areas, in general, experience significantly higher rates of obesity compared to those of urban areas (Jackson, Doescher, Jerant, & Hart, 2005), with approximately four in ten rural residents being classified as obese (Befort et al., 2012).

Several explainations for these disparities have been advanced. Some experts have argued that the observed disparities are due to differences in physical activity. Residents living in rural areas generally exercise less than those living in urban communities (Moore, Brinkley, Crawford, Evenson, & Brownson, 2013). This is due to inadequate facilities (e.g. municipal pools and gyms) and infrastructure (e.g. sidewalks and bike paths) (Banda et al., 2014; Robinson et al., 2014). The lack of physical activity may also be due to the built environment of rural communities; smaller, spread-out populations must rely exclusively on private transportation (Hansen, Umstattd Meyer, Lenardson, & Hartley, 2015).

Other studies have focused on food access and food choices as potentially important contributing factors in obesity disparities. Rural residents (34.4%) consume a slightly, but significantly higher percentage of calories from fat than their urban counterparts (33.6%) (Befort et al., 2012). This difference in diet may be due to the high cost of nutritious food. It is estimated that 16.5% of rural Americans live below the poverty line, a statistic higher than the national average, where approximately 15% of rural populations report being food insecure (Burton, Lichter, Macker, & Eason, 2013). Studies have shown that individuals who have to restrict their food costs chose lower-quality, high caloric foods that have little nutritional value (Dinour, Bergen, & Yeh, 2007). Despite the possible effect of poverty and physical activity on rural/urban disparities in obesity, research shows that this disparity persists even after controlling for age, gender, race, socio-economic status, and physical activities (Befort et al., 2012; Jackson et al., 2005). These findings suggest that the food environment (which dictates access) may be a relevant factor in explaining the rural/urban disparities in obesity rates.

Built-Food Environments and Obesity

Individual choices in food consumption are crucial to maintaining a healthy body weight (U.S. Department of Agriculture, 2015). The average adult makes 226.7 food-related decisions each day (Wansink & Sobal, 2007). Most choices are made unconsciously and are restricted or incentivized by the availability of food products in the surrounding food environment (Sobal & Wansink, 2008).

The built-food environment is characterized by the presence or absence of various types of food stores (Feng, Glass, Curriero, Stewart, & Schwartz, 2010). Previous research has demonstrated that different types of food outlets may increase or decrease the consumption of fruits/vegetables (Ahern, Brown, & Dukas, 2011; Bodor, Rice, Farley, Swalm, & Rose, 2010; Bonanno & Goetz, 2010; Currie, DellaVigna, Moretti, & Pathania, 2010; Galvez et al., 2009; Maddock, 2004; Morland & Evenson, 2009; Morland, Roux, & Wing, 2006; Wang, Kim, Gonzalez, MacLeod, & Winkleby, 2007; Yan, Bastian, & Griffin, 2015). Studies have shown that individuals, who live in a census tract with more convenience stores, consume fewer fruits and vegetables (Gustafson et al., 2011). Similarly, the presence and density of fast-food restaurants and convenience stores have been linked to increased rates of obesity (Bodor et al., 2010; Currie et al., 2010; Galvez et al., 2009; Li, Harmer, Cardinal, Bosworth, & Johnson-Shelton, 2009; Morland et al., 2006). Despite offering a diversity of specific foods necessary for a healthy diet, grocery stores and supercenters have differing effects on food consumption and obesity prevalence. While the presence of grocery stores is associated with higher rates of obesity (Morland & Evenson, 2009), research suggests that residents who do not live close to a grocery[1] store consume fewer fruits and vegetables (Sharkey, Johnson, & Dean, 2010). Interestingly, supercenters are related to a lower prevalence of obesity, despite having the same types of food products as grocery stores (Morland & Evenson, 2009; Morland et al., 2006). These inconsistent findings may be due to differences in rural and urban settings.

Rural/Urban Differences in Food Environments and Obesity

Recent studies have suggested that the relationship between food outlets and obesity differ in metropolitan and non-metropolitan areas. In metropolitan areas, the higher number of grocery stores per capita is related to a decrease in obesity rates (Yan et al., 2015); in non-metropolitan areas, more grocery stores are associated with higher obesity rates (Ahern et al., 2011). For counties located in non-metropolitan areas, fast-food restaurants per capita are associated with lower rates of obesity (Ahern et al., 2011), a finding that is inconsistent with studies examining metropolitan areas (Bodor et al., 2010; Li et al., 2009). Although evidence suggests that obesity prevalence is higher in areas with more grocery stores or fast-food restaurants in the Southern region of the US (Morland & Evenson, 2009), this association was not found in a study conducted in California (An & Sturm, 2012). In a study that examined the rural Appalachian region of Ohio, low availability of all food stores predicted higher body weight (Holben & Pheley, 2006). These findings suggest that food environments and their impact on obesity may vary significantly across communities and regions throughout the US.

Food Environment in the Appalachian Region

The Appalachian Region consists of 420 counties and 25 million residents across 13 states (Appalachian Regional Commission, 2011). This region has historically experienced higher rates of poverty and has slightly double the number of residents living in rural areas (42%) as compared to the national average (Appalachian Regional Commission, 2011). In 1965, the federal government created the Appalachian Regional Commission (ARC) to address the

[1] According to United States Department of Agriculture (2014), grocery stores "are generally known as supermarkets and smaller grocery stores primarily engaged in retailing a general line of food" (p.11) such as Kroger in Pittsburgh. Supercenters are large general merchandise stores that "primarily engaged in retailing a general line of groceries in combination with general lines of new merchandise, such as apparel, furniture, and appliances" (p. 13). For example, Wal-Mart is considered a supercenter.

economic and social disparities between the Appalachian region and the rest of the US (Appalachian Regional Commission, 1964). While the region has experienced notable growth over the past fifty years, economic deprivation and concentrated poverty continue to be a critical issue that may lead to poor health outcomes, such as high mortality rates (Hendryx, 2012), lower rates of access to healthy food, and higher rates of obesity (Black, 2014). Eighty-one percent of mountaintop areas (Kentucky, Tennessee, and West Virginia), and 75% of counties in Alabama, Georgia, Mississippi, and South Carolina report obesity rates higher than the national average (CDC, 2009). As of 2013, the estimated annual cost for obesity-related diabetes across the Appalachian region had reached 1.9 billion dollars (Herath, Brown, & Hill, 2013).

The economic deprivation and poverty concentration in Appalachia may shape its food environment. In a study that examined all food deserts at the county level in the US, the Appalachian region of Kentucky and West Virginia were among the four US regions with the most counties considered food deserts (Morton & Blanchard, 2007). The prevalence of food deserts in these areas may be due to the high concentrations of poverty related to the coal mining industry (Borak, Salipante-Zaidel, Slade, & Fields, 2012). Low-income neighborhoods consistently have fewer chain grocery stores than middle-income neighborhoods (Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007). These trends may be due to market forces that dictate store locations to maximize profits. For example, there is little economic incentive for chain grocery stores to locate in low-density, high-poverty areas due to the lack of consumers' willingness and ability to spend money in their stores (Huff, 1966). The size of the potential market also dictates the size of the store needed to maximize profits. When less-profit potential is estimated, or realized, businesses are not able to sustain the operating cost of large facilities, resulting in rural disadvantaged areas having smaller stores with less selection (Huff, 1966). Due to these market dynamics, individuals living in areas with low populations and high poverty, for example, those found in Appalachia, generally have less access to stores (Jilcott, McGuirt, Imai, & Evenson, 2010; Sharkey et al., 2010).

Although researchers have investigated the general patterns of food environments and their impact on obesity rates, few studies have examined this relationship in the Appalachian region. Previous studies have assumed the food environment to be static. Few studies have measured how the food environment changes over time and how these changes affect obesity. In this study, we examined the food environment changes over time and the impact on county-level obesity prevalence in the Appalachian Region. Based on previous literature, we hypothesized that: 1) An increase of grocery stores would be associated with higher county-level obesity rates in the Appalachian region (H1); 2) An increase of supercenters would be associated with higher county-level obesity rates in the Appalachian region (H2); 3) An increase of convenience stores would be associated with higher county-level obesity rates in the Appalachian region (H3); and 4) An increase of fast-food restaurants would be associated with higher county-level obesity rates in the Appalachian region (H4).

METHODS

To test these hypotheses, we used data collected as part of the Behavioral Risk Factor Surveillance System, the American Community Survey, and the Food Environment Atlas. Data analysis included 412 counties within the Appalachian region (Appalachian Regional Commission, 2011).

The Behavioral Risk Factor Surveillance System.

Age-adjusted obesity rates for each county within the Appalachian region was obtained from the Center of Disease Control National Center Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS and the US Census Bureau's Population Estimates Program estimated the age-adjusted obesity rate (county-level age-adjusted obesity rate) (CDC, 2012a). The estimated obesity rate pertains to the adult population, aged 18 years or older, who live in US households (BRFSS, 2017).

BRFSS uses random-digit dialing to collect health-survey data on adult US residents in areas of health-related risk behaviors, chronic health conditions, and use of preventive services (BRFSS, 2017). BRFSS completes more than 400, 000 adult interviews each year in all 50 states, the District of Columbia, and Puerto Rico. The weighting methodology used in this data is termed *interactive iterative proportional fitting* (raking). Raking adjusts the survey data so that groups underrepresented in the sample are more accurately represented in the final data (BRFSS, 2017). The data collection process is sponsored by multiple agencies, including most divisions in the Center of Disease Control National Center for Chronic Disease Prevention and Health Promotion, and federal agencies such as Substance Abuse and Mental Health Services Administration.

The Food Environment Atlas

Food environment indictors were obtained from the United States Department of Agriculture (USDA) Economic Research Service (ERS) Food Environment Atlas (the Atlas). The Atlas is a publicly-available data source that provides a spatial overview of a community's ability to access food resources (Economic Research Service, 2016). It can be a useful source for characterizing counties and states on food environment (Longacre et al., 2011). This dataset provides more than 160 food-environment indicators at the county level in the US, including the availability of food stores, food prices, food and nutrition assistance programs, and other socio-economic characteristics that may influence healthy food access and consumption (Chi, Grigsby-Toussaint, Bradford, & Choi, 2013).

We used the 2014 Atlas dataset in our data analysis and manually selected the county data within the Appalachian region. The 2014 Atlas dataset provides an estimation of changes in food-environment indictors from 2007 to 2011, including the percentage of change of grocery stores per 1,000 county residents, supercenters per 1,000 county residents, convenience stores per 1,000 county residents, and fast-food restaurants per 1,000 county residents (See Table 1 for links to these data sources).

Table 1. Description of data and data sources

Variables	Description of Variables	Year	Data Type	Source (Link)
% Obesity	Proportion of adults whose body mass index is 30 or greater	2006, 2012	County level rate	Centers for Disease Control and Prevention: Obesity county data (https://www.cdc.gov/diabetes/data/countydata/countydataindicators.html)
% Rural	Proportion of the county population living in areas with population fewer than 2,500 people	2006-2010 (5-year estimates)	County level rate	United States Census Bureau (https://www.census.gov/programs-surveys/acs/data.html)
% Poverty	Proportion of county population living in households with income below the poverty threshold	2006-2010 (5-year estimates)	County level rate	
% Change grocery store	Percent change in the number of grocery stores per 1,000 county residents from 2007 to 2011	2007-2011	County level rate	Food environment atlas (https://www.ers.usda.gov/data-products/food-environment-atlas/data-access-and-documentation-downloads/)
% Change fast-food restaurants	Percent change in the number of fast-food restaurants per 1,000 county residents (per capita) from 2007 to 2011	2007-2011	County level rate	
% Change convenient stores	Percent change in the number of convenient stores per 1,000 county residents from 2007 to 2011	2007-2011	County level rate	

The American Community Survey

Poverty rates and rural area rates for each county within the Appalachian region were obtained from the U.S. Census Bureau American Community Survey (ACS). ACS is a nationwide survey conducted by the US Census Bureau, designed to provide information about annual demographics, social, economic, and housing data for US communities (The U.S. Census

Bureau, 2008). ACS samples nearly three million addresses each year, which results in approximately two million interviews. The US Census Bureau releases data on one-year, three-year, and five-year estimates on topics regarding the social, economic, demographic, and housing characteristics of the US population. A one-year estimate included data collected over a 12-month period; a three-year estimate included data collected over a 36-month period; and a five-year estimate included data collected over a 60-month period.

In this study, we used a five-year estimation (2006-2010) of poverty rates and rural area rates for each county (hereafter county-level poverty rates and county-level rural area rates, respectively). The primary reason for using the five-year estimation is that it provides more statistically reliable data on less populated areas and small population subgroups. This is suitable for analyzing rural areas, such as the Appalachian region, because rural areas in the US cover 97% of the nation's land, but contain only 19.3 % of the population (The U.S. Census Bureau, 2017a).

Measurements

In this study, all variables are measured at the county level. The *dependent variable* in this study is the 2012 age-adjusted, county-level adult obesity rate. This variable is part of the dataset. The obesity rate is the proportion of adults (≥ age 18) whose body mass index (weight [kg]/height $[m]^2$) is 30 or greater in a given county. This obesity rate is adjusted by employing the direct method (Anderson & Rosenberg, 1998) to the 2000 U.S. census population using the age groups 20–39, 40–59, and 60 and over (CDC, 2012b). The *independent variables* in this study are the percent change in the number of food stores per 1,000 county residents (per capita) from 2007 to 2011 in a given county. In this study, we examined the percent change of grocery stores per capita, supercenters per capita, convenience stores per capita, and fast-food restaurants per capita. These indicators are also part of the dataset. This is how these indicators are calculated in the dataset: In a given county, the percent change in the number of grocery stores per capita from 2007 to 2011 is calculated as $(G_{2011} - G_{2007}) / G_{2007}) * 100$, where G_{2011} is the number of grocery stores in the county per capita in 2011 and G_{2007} is the number of grocery stores in the county per capita in 2007 (Economic Research Service, 2014). Economic Research Service (2014) applies this method to calculate the percent change from 2007 to 2011 in the number of supercenters per capita, convenience stores per capita, and fast-food restaurants per capita.

The *control variables* are the age-adjusted obesity rates in 2007 rural area rates, and the poverty rates at county level in the Appalachian region. The 2007 age-adjusted county-level adult obesity rate is the proportion of adults whose body mass index is 30 or greater in a given county, and the adjusted rate is calculated using the direct method (Anderson & Rosenberg, 1998) to the 2000 U.S. census population using the age groups 20–39, 40–59, and 60 and over (CDC, 2012b). Rural areas refer to the territories that are not included within an urban area (an urban area is defined as the population greater than 2,500 people)(The U.S. Census Bureau, 2017b). The rural area rate in a given county is the proportion of the county population living in areas with a population of fewer than 2,500 people (The U.S. Census Bureau, 2017b). The poverty rates in a given county is the proportion of its population living in households with an income below the poverty threshold (The U.S. Census Bureau, 2009). For each of the variables, we used the mean in the model estimation, which was the sum of all county rates divided by the number of counties.

Statistical analysis

The unit of the data analysis is at the county level. Each county represents an observation. We first merged our data from multiple data sources by county names. Next, we conducted missing data imputation, descriptive statistical analysis (mapping), bivariate analysis, and parameter estimates in multivariate regression models. A total of 37 observations (approximately 9% of the total) were found missing in the number of grocery stores and convenience stores per capita. To address this issue, we conducted multiple imputations using the EMB algorithm (Expectation Maximization and Bayesian classification model) (Honaker, King, & Blackwell, 2011), based on the assumption that the data were missing at random. The imputed data was used in our final data analysis. Descriptive analyses, including mapping, were used to assess the characteristics of Appalachian region counties and the change in food availability indicators. A correlation matrix was used to examine the bivariate relationships between the outcome variable and its covariates.

Prior to fitting the ordinary least squares (OLS) regression model, we applied a log transformation to obtain an approximate normal distribution of the dependent variable, and standardized the independent variables to have a mean of zero and unit variance. This method was employed to meet the assumption in the general regression model estimation, as suggested in previous studies (Collins, Babyak, & Molone, 2006). We then used a step-wise method to estimate parameters in the regression models. Model 1 to Model 4 examined the relationship between obesity and the change in each indicator of the food environment, controlling for the poverty rate, rural area rate, and obesity rate in 2006. Model 5 included all food environment indicators. Shape files and maps were created in Quantum Geographic Information System version 2.12.3 (Nanni et al., 2012). Data pre-processing and analyses were conducted in R programming language version 3.2.2 (Ihaka & Gentleman, 1996)

RESULTS

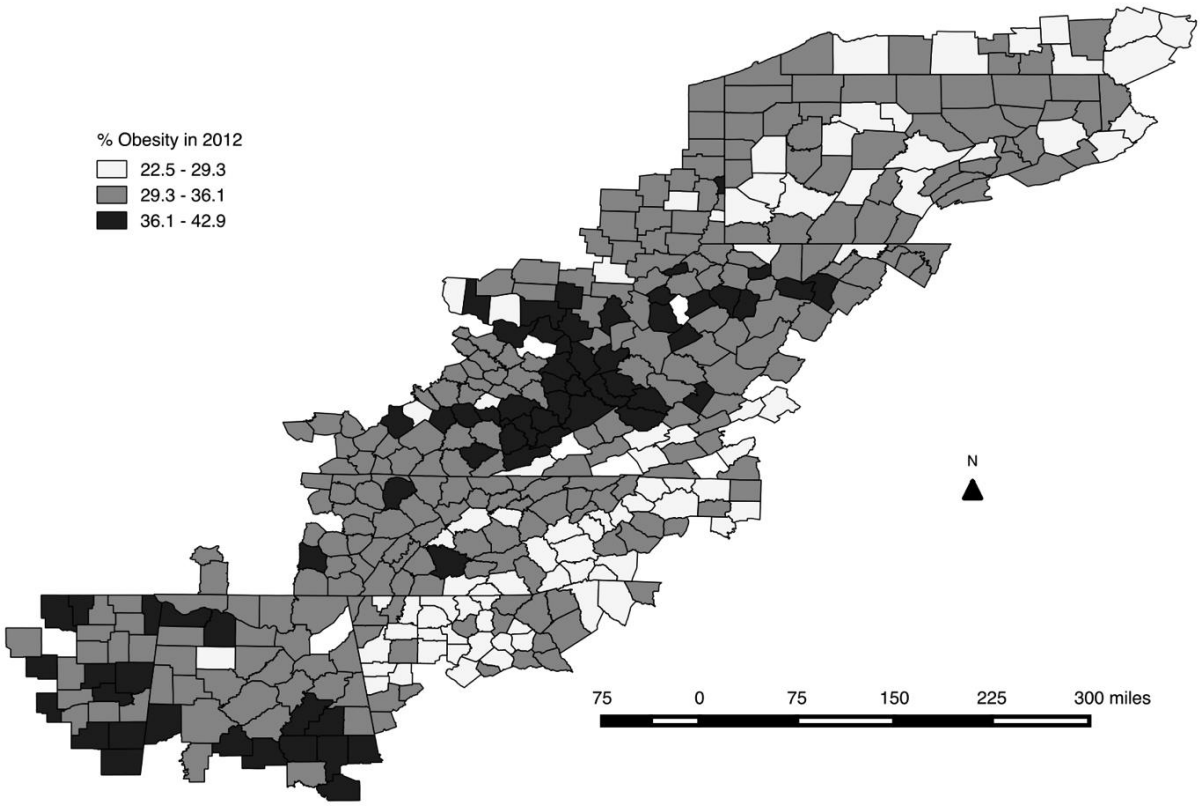
Descriptive analysis

Table 2. Descriptive statistics for each variable at county-level (N=406)

Variables	Mean (SD)	Min	Max
% Rural	68 (.25)	.00	1.00
% Poverty	17.67 (8.37)	.09	40.1
% Change Grocery store	-11.89 (28.88)	-100	193.55
% Change Fast-food restaurants	-3.28 (27.68)	-100	298.88
% Change Convenient stores	-4.77(20.61)	-63.50	102.97
% Change Super Centers	7.47 (28.18)	-51.25	275.82
% Obesity in 2007	36.17(2.39)	23.9	47.8
% Obesity in 2012	32.54 (3.77)	22.50	42.90

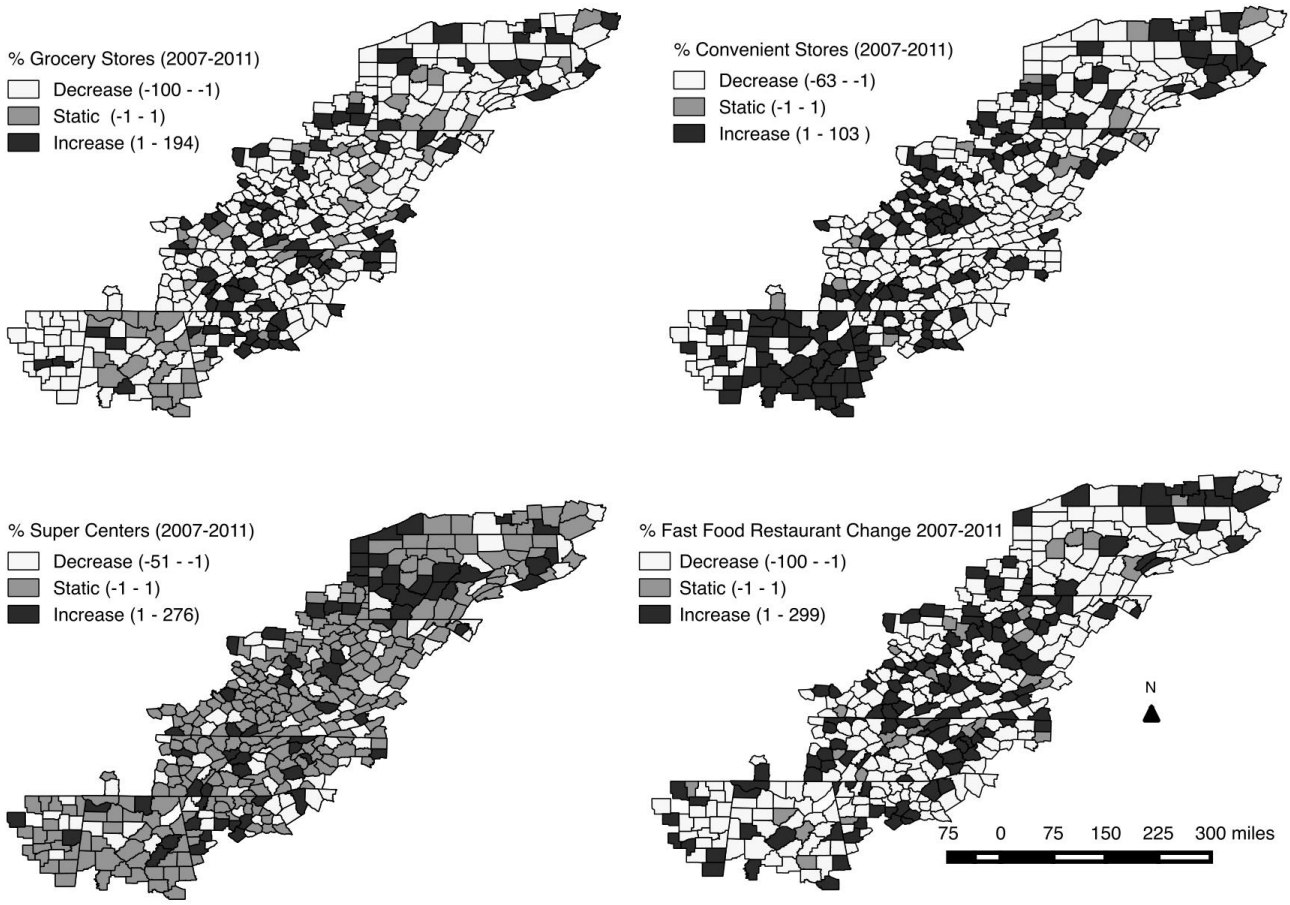
Table 2 details the county-level variables included in this study. At the county-level in the Appalachian region, the average rural area rate was 68% (*SD* = .25; *min* = 0; *max* = 1), and the average poverty rate was 17.67% (*SD* = 8.37; *min* = .09; *max* = .40.1). From 2007 to 2011, there was an average percent decrease of grocery stores per capita (*M* = -.11.89 *SD* = 28.88, *min* = -100, *max* = 193.55), fast-food restaurants per capita (*M* = -3.28, *SD* = 27.68, *min* = -100, max = 298.88), and convenience stores per capita (*M* = -4.77, SD= 20.61. min= -63.50; max= 102.97). During the same period, this region experienced an increase in the average percent of supercenters per capita (*M* = 7.47, SD= 28.18; min = -51.25; max= 275.82). In the Appalachian region, the average age-adjusted obesity rate in 2012 was 32.54% (*SD* = 3.77), with the lowest obesity rate occurring in Buncombe County, North Carolina (22.5%), and the highest rate occurring in Breathitt County, Kentucky (43%). Figure 1 classifies the obesity rates into four quantiles (equal count per quantile) and confirms the large variance of county-level, age-adjusted obesity rates in this region, suggesting that the higher rates are mostly concentrated within counties located in the Appalachian Central and Southern sub-regions.

Figure 1. The 2012 age-adjusted obesity rate in Appalachian region



In 2007, the average number of food stores was less than one store per capita in Appalachian region counties, with convenience stores being the most prevalent (about .64 per capita) and grocery stores being the least prevalent (about .01 per capita). From 2007 to 2011, even though there was an increase of supercenters per capita in the Appalachian region, there was an overall decrease of food availability. As indicated in Figure 2, more than 50% of all the counties in the Appalachian region had a decrease in grocery stores (n_g = 292), convenience stores (n_c =256), and fast-food restaurants (n_f =259). Among the counties in this region, Garrard County, Kentucky saw the sharpest decrease in the rate of grocery stores (-100 %); Robertson County, Kentucky saw the sharpest decrease in fast-food restaurants (-100 %); Forest County, Pennsylvania saw the sharpest decrease in convenience stores (-63.50 %); and Pike County, Ohio saw the sharpest decrease in grocery stores (-63.50 %).

Figure 2. The change of grocery stores, convenient stores, supercenters, and fast-food restaurants in Appalachian region: 2007-2011



Correlations were used to examine bivariate relationships between the examined variables (see Table 3). The obesity rate in 2012 was positively associated with the rural area rate (r = .22, p < .01), the poverty rate (r = .34, p < .01), the change of convenience stores from 2007 to 2011 (r = .08, p < .05), and the obesity rate in 2007 (r = .66, p < .001). The obesity rate in 2012 was negatively associated with the percent change of grocery stores per capita (r = -.16, p < .01) and the change of supercenters per capita (r = -.13, p < .01) from 2007 to 2011. The poverty rate was found to be positively associated with the rural area rate (r = .35, p < .01), and negatively associated with the percent change of supercenters per capita from 2007 to 2011 (r = -.07, p < .001). There was also a positive association between the change of convenience stores per capita and the change of fast-food restaurants per capita (r = .13, p < .01).

Table 3. Correlation matrix for each variable included in this study

	1	2	3	4	5	6	7	8
1. % Obesity in 2012	__							
2. % Rural	.22**							
3. % Poverty	.34 **	.35**	__					
4. % Change Grocery Stores	-.16**	.01	-.08	__				
5. % Change Fast-food restaurants	-.02	.01	.08	-.02	__			
6. % Change Convenient stores	.08*	.02	.08	-.12*	.13**	__		
7. % Change Super Centers	-.13**	-.42***	-.07**	.06	.01	.02	__	
8. % Obesity in 2007	.66***	-.39***	.44***	-.08*	.02	.06	-.19***	__

Ordinary Least Squares (OLS) Regression

We conducted OLS regression to further examine the associations between the obesity rate in 2012 and the percent change in the number of grocery stores per capita, and supercenters per capita, convenience stores per capita, and fast-food restaurants per capita from 2007 to 2011. To test our hypotheses, we took the stepwise approach and constructed models to test posed hypotheses. Model 1 to Model 4 corresponds to H1 to H4, respectively (see Table 1). For all the models, we controlled for the county-level, age-adjusted, obesity rates of 2007, the county-level poverty rates, and the county-level rural area rates.

Obesity rates and grocery stores

In model 1, we tested our H1 that posed an increase of grocery stores would be associated with higher county-level obesity rates in the Appalachian region. Our model showed that the decrease in the number of grocery stores per capita, from 2007 to 2011, was significantly associated with an increased obesity rate for 2012, after the county-level, age-adjusted obesity rates of 2007, the county-level poverty rates, and the county-level rural area rates ($\beta(SE)$ = -.012(.004), $p < .01$). Therefore, in the Appalachian region, from 2007 to 2011, for each one-unit decrease of per capita grocery stores at the county level, we could expect a 1.2 percent increase in the county-level age-adjusted obesity rate of 2012.

Obesity rates and supercenters, convenience stores, and fast-food restaurants

In Models 2, 3, and 4, we tested our hypotheses on the association between county-level obesity rates and the increase of supercenters (H2), convenience stores (H3), and fast-food restaurants (H4). No significant associations were found between the age-adjusted obesity rates of 2012 and the percent change in the number of supercenters per capita, convenience stores per capita, and fast-food restaurants per capita from 2007 to 2011. In Model 5, we included these food environment indicators to predict the obesity rate of 2012, controlling the county-level, age-adjusted obesity rate of 2007, county-level poverty rates, and county-level rural area rates. The decrease in the number of grocery stores per capita from 2007 to 2011 was still found to be

associated with the higher obesity rate of 2012 at a significant level, ($\beta(SE)$ = -.011 (.004), p < .01).

Table 4. Ordinary least squares (OLS) regression models for predicting obesity

		Estimates (SE)				
Independent Variables		Model 1	Model 2	Model 3	Model 4	Model 5
				.004(.004)		.003(.004)
% Change of Convenience stores						
% Change of Fast-food restaurants					-.002(.002)	-.004(.004)
% Change of Grocery stores		**-.012(.004)****				**-.011(.004)****
% Change of Supercenters			-.003(0.002)			-.003(.005)
Covariates						
% Obesity in 2007		.077(.005)***	.077(.005)***	.077(.005)***	.077(.005)***	.076(.005)***
% Rural		-.005(.005)	-.007(.005)	-.006(.005)	-.006(.005)	-.006(.005)
% Poverty		.005(.005)	.006(.005)	.006(.005)	.006(.005)	.006(.005)***
Model information	R^2	.45	.44	.44	.43	.45
	F	82.02***	78.96***	79.08***	79.05***	46.96***
	RMSE	.089	.089	.089	.089	.089

Note. *p <.05; **p <.01; ***p <.001

DISCUSSION

This study extends previous research examining the relationship between food environments and obesity by testing the relationship between food environment changes and obesity in the Appalachian region. The findings of this study support the hypothesis that there is a relationship between changes in grocery stores per capita and obesity rates at the county level. The finding, however, revealed a relationship in the opposite direction hypothesized. Increases in grocery stores were associated with decreases in county-level obesity rates, rather than with the increase in county-level obesity rates as we hypothesized (H1). Although this finding was counter to Ahern et al.'s (2011) findings that grocery stores were associated with higher rates of obesity in rural areas, it is consistent with the findings of Inagami and colleague's (2006) study which found that a lower density of grocery stores is associated with greater levels of obesity. Additional studies conducted at the individual level found the lack of access to grocery stores was significantly associated with increased individual obesity (Bodor et al., 2010). In contrast to several previous studies (Currie et al., 2010; Galvez et al., 2009; Volpe, Okrent, & Leibtag,

2013), no support was found for the relationship between the obesity rates at the county level and changes in convenience stores (H2), supercenters (H3) , and fast-food restaurants (H4). While convenience stores, supercenters, and fast-food restaurants experienced change over time, it is possible that at the beginning of this study the high rates of obesity in this region made it less likely that changes in the food environment would make a significant difference within the short study period.

Similar to Black's (2014) findings, the percentage of the county that was rural and living below the poverty line was significantly related to county-level obesity rates. However, when changes in the food environment were considered, controlling for the obesity rates of 2007, these relationships were no longer significant. Either obesity is increasing at similar rates in both rural areas or the changes in the food enviroment are impacting the differing rates of obesity of the rural/urban areas. If the changes in the food enviroment acount for the rural/urban disparities in obestiy, these findings may suggest that market forces are dictating the location of grocery stores--driving stores in higher-poverty rural areas to close and/or relocate to higher-income urban areas. Yet, no significant relationship was found between the poverty rate and the decrease in grocery store change at the county level. It may, however, be the case that the movement of grocery stores at a smaller geographical level is responsive to market forces, in this case poverty, and that these effects are simply not observed at the county level. It should also be noted that the direction of the relationship between rural areas and obesity is the opposite of what has been found in previous studies. Black (2014) found a negative relationship between the percentage of rural areas in counties and obesity, whereas this study found a positive relationship. This association may suggest possible contextual differences in the Appalachian region when compared to other parts of the US.

In this study, we found an overall decrease in food stores per capita (grocery stores, convenience stores, and fast-food restaurants) and an increase in supercenters from 2007 to 2011. Although it has been argued that the change in supercenters will increase access to healthy food in the same manner as an increase in grocery stores (Volpe et al., 2013), this was not demonstrated in our findings. This circumstance is especially important due to the general increase in supercenters against the decrease in all other types of food outlets observed throughout the Appalachian region. It may be that the rise in supercenters is decreasing the economic viability of smaller grocery stores--a trend that may have an impact on public health, given the protective effect of increases in grocery stores as suggested in this study. It should be noted that in the bivariate correlations, there was a significant negative association between obesity in 2012 and the change in supercenters, a pattern that is consistent with the association between grocery stores and obesity. There was also a significant negative association between the change in supercenters and poverty. This indicates that while supercenters may have a similar protective effect, their location in more economically advantaged areas does not provide the same protection as grocery stores, whose change does not vary according to poverty levels by county.

The location of supercenters in more economically advantaged counties makes economic sense and yet, this factor may be threatening the viability of grocery stores due to cheaper prices and a wider variety of goods that incentivize individuals to make long trips to purchase food. The necessity of traveling long distances through rural areas to obtain food at lower prices may, however, shift individuals' consumption patterns from the perishable fruits, vegetables, lean

protein, and low-fat dairy crucial to a healthy diet to more processed foods that can keep for longer periods of time and travel well. The lack of a significant association between convenience stores and fast-food restaurants may also indicate differences in the Appalachian region in comparison with other regions in the US. It is again important to note that, on average, while convenience stores and fast-food restaurants changed over the study period, very few counties displayed no change, indicating dynamic food environments across the region. Significantly less change was observed in supercenters, which is likely due to the expense of opening these types of retail stores, a general lack of competition, and the need for a greater consumer population to support each supercenter, in comparison to other food outlets.

Our results suggest the importance of studying food environments as a dynamic process. Although it is generally believed that increasing access to healthy food may have a significant health impact, our results indicate that these changes are happening naturally and may be in response to market forces. Overall, the findings of this study indicate that the relationship between the food environment and the obesity rates in other regions of the US may not reflect their association in the Appalachian region. These regional variations may be due to factors separating Appalachia from other regions, including a relatively sparse population in comparison to adjacent regions, and a historically comparative lack of outside retail investment. The significant correlation between the percentage of poverty and the percentage of ruralism in the Appalachian region is also especially important. Poverty rates observed in the Appalachian region may be associated with stressors (other than food access) that put these counties at risk for higher rates of obesity and the attendant health issues. It is also possible that much of the variance in the relationship between the percentage of ruralism and obesity is accounted for when adjusting for the obesity rate of 2006, due to the variations in economic wellbeing, population size, and composition across sub-regions within greater Appalachia.

Further investigation is needed to more completely examine food environment changes in other regions and their associations with widespread obesity. Our findings regarding changing food environments may provide insight for how food deserts were created and how they affect the high prevalence of county-level obesity in the Appalachian region. In our study, counties in the Central Appalachian sub-region that were found to be mostly economically deprived, experienced sharper decreases in the number of food stores, and exhibited higher obesity prevalence. This may indicate a potential cycle in economically deprived counties: the greater the rate of economic deprivation, the sharper the decrease in the number of food stores, and consequently, the higher the prevalence of obesity. These trends may be related in part to a traditional food retail business model in which stores move away from low-income and sparsely populated communities and gravitate to higher-income areas and communities with dense enough populations to support the financial bottom-line. This creates barriers to healthy food access for residents living in rural areas and/or areas with high poverty.

Further investigation is also needed to asses the interaction between individual income and food enviroments. Although this study controlled for county-level poverty, previous research has shown that food choice is heavily impacted by individual income and programs designed to supplement food access like SNAP. This is not to say that the food environment is not important. It is certainly true that the food environment restricts access and choice given a set income. However, the limits of income and dwindling food budgets over the course of a month may amplify the impact of these environments and should be considered in future studies.

Limitations

While this study highlights an important topic and has several strengths, it is not without limitations. First, this study focused on how food environments changed from 2007 to 2011, which potentially limits its generalizability to other time periods. Future studies may examine obesity rates and food environment changes across multiple periods and provide broader statistics that will support stronger causal arguments. Second, because of the unique features of the Appalachian region, these findings may not be generalized to other areas of the US. Third, this study focuses on county-level processes and does not take into account individual-level behavior. Consequently, individuals' risk factors for obesity, such as activity levels and individual income that might restrict food access are not accounted for. County-level data can provide insights into what may contribute to obesity rates at the county level, such as the food environment, but would not explain why some individuals are more obese than others within the county.

CONCLUSION

This study examined the relationship between changes in the food environment and obesity and found that decreases in grocery stores were related to increases in obesity. This finding indicates a potential place for intervention. It has been assumed that the growth in supercenters would replace grocery stores and provide continued access to healthy fruits and vegetables needed to maintain a healthy diet. This, however, was not observed in the study. Economic incentives may be necessary to maintain smaller grocery stores in order to address the high rates of obesity in the Appalachian region. Additionally, this study suggests that food environments are rapidly changing, and that examining changes in the food environment may provide important insight into how food environments evolve over time and how that evolution impacts public health outcomes such as obesity. Overall, this study suggests that increasing the number of grocery stores may be an important aspect of intervention aimed at addressing the high rates of obesity in the Appalachian region

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