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Scale effects in food environment research: Implications from assessing socioeconomic dimensions of supermarket accessibility in an eight-county region of South Carolina

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ABSTRACT

Choice of neighborhood scale affects associations between environmental attributes and health-related outcomes. This phenomenon, a part of the modifiable areal unit problem, has been described fully in geography but not as it relates to food environment research. Using two administrative-based geographic boundaries (census tracts and block groups), supermarket geographic measures (density, cumulative opportunity and distance to nearest) were created to examine differences by scale and associations between three common U.S. Census–based socioeconomic status (SES) characteristics (median household income, percentage of population living below poverty and percentage of population with at least a high school education) and a summary neighborhood SES z-score in an eight-county region of South Carolina. General linear mixed-models were used. Overall, both supermarket density and cumulative opportunity were higher when using census tract boundaries compared to block groups. In analytic models, higher median household income was significantly associated with lower neighborhood supermarket density and lower cumulative opportunity using either the census tract or block group boundaries, and neighborhood poverty was positively associated with supermarket density and cumulative opportunity. Both median household income and percent high school education were positively associated with distance to nearest supermarket using either boundary definition, whereas neighborhood poverty had an inverse association. Findings from this study support the premise that supermarket measures can differ by choice of geographic scale and can influence associations between measures. Researchers should consider the most appropriate geographic scale carefully when conducting food environment studies.

1. Introduction

Over the past decade, in efforts to combat food insecurity and the obesity epidemic, researchers and policymakers have been concerned with the influence of local food environments and disparities in food access (Larson, Story, & Nelson, 2009). In investigating this issue, many studies have shown significant associations between the neighborhood food environment, diet and obesity (Caspi, Sorensen, Subramanian, & Kawachi, 2012; Morland & Evenson, 2009; Wang, Kim, Gonzalez, MacLeod, & Winkleby, 2007); however, many other have suggested that no significant relationship exists (Hattori, An, & Sturm, 2013). Inconsistencies between findings could perhaps be due to how neighborhood and local food environments have been defined (Liu, Han, & Cohen, 2015).

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Food environments have been characterized in many ways, with geographic information systems (GIS) being the most frequently used analytical tool (Caspi et al., 2012; Charreire et al., 2010; Larson & Story, 2009; Larson et al., 2009; Thornton, Pearce, & Kavanagh, 2011). Using GIS, geographic-based measures of availability and accessibility of specific food retailers (e.g., supermarkets) and healthier or less-healthful foods have been created (Apparicio, Cloutier, & Shearmur, 2007; Charreire et al., 2010; Kelly, Flood, & Yeatman, 2011; Larsen & Gilliland, 2008; Thornton et al., 2011). Availability is typically defined as the presence or count of an attribute, e.g., supermarkets, in a defined area (Charreire et al., 2010; Thornton et al., 2011). Availability can also be represented as a density, e.g., the number of supermarkets per population or per geographic area (Thornton et al., 2011). Accessibility has been defined as ease of access to available supermarkets, taking factors such as travel distance, travel time and financial resources into consideration (Thornton et al., 2011). Accessibility has been extensively measured within the field of geography (Geurs & van Wee, 2004; Handy & Niemeier, 1997). The simplest measure of access—distance or proximity to the nearest supermarket—has been most commonly used in food environment research. However, accessibility has also been characterized by several other measures, including the cumulative opportunity index (Thornton et al., 2011; Van Meter et al., 2010, 2011).

Studies have pointed out several challenges when deriving geographic measures of the food environment (Fleischhacker, Evenson, Sharkey, Pitts, & Rodriguez, 2013; Liese et al., 2010, 2013). Problems with GIS include count, type and spatial inaccuracies when using secondary, commercial databases (Liese et al., 2013). These issues have generally led to under- or over-counting of food venues and misclassification of venue type and have risked mixed, diminished or overstated findings and effects of associations. To improve data quality and minimize measurement error, researchers are increasingly conducting primary data collection and field validation (Fleischhacker et al., 2013).

Less discussed is the choice of appropriate “neighborhood” boundaries or scale and the geographic context in which to operationalize food environment data (Fan et al., 2014; Larson et al., 2009; Liu et al., 2015). Many geographical boundaries have been used to define neighborhood food environments, ranging from egocentric buffer distances of 100 m–2.5 km (~1.6 miles) around individual residential, worksite or school addresses or using administrative-based units, e.g., census tracts or block groups (Caspi et al., 2012; Charreire et al., 2010; Fan et al., 2014; Liu et al., 2015). However, there is no consistent methodology with which food environment researchers have agreed to construct geographic measures. Therefore, when comparing findings across studies, the measurements of neighborhood food exposure can vary depending on the geographical units selected. In geography, this effect is attributed to the modifiable areal unit problem (MAUP) (Fotheringham & Wong, 1991; Flowerdew, Manley, & Sabel, 2008; Haynes, Daras, Reading, & Jones, 2007; Openshaw, 1983; Schuurman, Bell, Dunn, & Oliver, 2007).

The MAUP is composed of two aspects, a scale effect and zonation effect, which through their tandem relationship can have significant influence on characterizing and modeling associations between the environment and health-related outcomes (Flowerdew et al., 2008; Haynes et al., 2007; Jackson, Davies, & Leyland, 2010; Reijneveld, Verheij, & de Bakker, 2000; Oliver & Hayes, 2007; Martikainen, Kauppinen, & Valkonen, 2003; Ross, Tremblay, & Graham, 2004; Oliver & Hayes, 2007). The scale effect causes analytical differences based on the size and number of geographic units used. Thus, associations will vary based on how refined and robust the measures are for these different geographic units (Oliver & Hayes, 2007; Parenteau & Sawada, 2011). Understanding the scale effect and the associated MAUP is particularly important for many geographic-related analyses (Kwan & Weber, 2008).

To the best of our knowledge, scale effects have not been well explored in food environment research, although one of the most probable contributors to the many mixed findings relating neighborhood food environments to diet and/or weight is the choice of geographic scale (Fan et al., 2014; Liu et al., 2015). To date, only one study has explicitly examined the effect of geographic scale on detecting relationships using a neighborhood food environment measure (Fan et al., 2014). In cross-sectional analyses comparing four different scales, Fan and colleagues found that the choice of neighborhood geographic scale did affect the estimated significance of the association between neighborhood food environments and individual obesity risk. Specifically, if the relevant neighborhood is defined as too large, (i.e., larger than a census tract for a convenience store or full-service restaurant) or too small (smaller than a census tract for limited-service restaurants), then the statistical relationship became insignificant (Fan et al., 2014). However, this study had several limitations, including the use of a secondary database to define the food environment and using only store count as the measurement criteria.

The objective of this study, therefore, was to evaluate the influence of two commonly used administrative-based geographic definitions (i.e., census tract and block group) on the relationships between GIS-derived supermarket measures and common U.S. Census-based socioeconomic characteristics using data from a 2010 South Carolina food environment study (Liese et al., 2010, 2013; Van Meter et al. 2010, 2011). Supermarkets were selected for this analysis because compared with other food retailers, they provide access to a greater quantity, variety and quality of food items (Block & Kouba, 2006; Franco, Diez-Roux, Glass, Caballero, & Brancati, 2008) and have been used as a major criterion of the quality of the food environment in many studies (Križan, Bilková, Zubriczky, Riška, & Barlík, 2014; Larson et al., 2009; Bader, Purciel, Yousefzadeh, & Neckerman, 2010; U.S. Department of Agriculture, 2009). The association of supermarket measures and neighborhood socioeconomic characteristics was used because previous studies have shown significant associations between these attributes (Beaulac, Kristjansson, & Cummins, 2009; Larson et al., 2009; Moore & Diez-Roux, 2006; Morland, Wing, Diez-Roux, & Poole, 2002; Morland & Filomena, 2007; Powell, Chaloupka, & Bao, 2007a, 2007b; Sharkey & Horel, 2008; Walker, Keane, & Burke, 2010; Zenk et al., 2005).

2. Methods

2.1. Study design

This analysis was part of a large methodological study of the food environment in South Carolina (Liese et al., 2010, 2013; Van Meter et al., 2010, 2011). The study area consisted of a contiguous geographical area and encompassed eight counties in the Midlands region of the state. The project's efforts established a spatially and temporally verified database comprising 2,208 food outlets in South Carolina, including the global positioning system coordinates of all retail food outlets (Liese et al., 2010, 2013). This study was reviewed and deemed exempt by the Institutional Review Board of the University of South Carolina.

2.2. Neighborhood geographic boundaries

Two geographic units were selected for analysis. Data were based on both the census tract and block group administratively defined geographical boundaries obtained from the 2000 U S.