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Running to the Store? The Relationship between Neighborhood Environments and the Risk of Obesity

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Abstract

We expand the search for modifiable features of neighborhood environments and obesity risk in two ways. First, we examine both residents' access to neighborhood retail food options in combination with neighborhood features that facilitate physical activity. Second, we evaluate neighborhood features for both low income and non-low income neighborhoods (bottom quartile of median neighborhood income vs. the top three quartiles).

Our analyses use data from the Utah Population Database merged with U.S. Census data and Dun & Bradstreet business data for Salt Lake County, Utah. Linear regressions for BMI and logistic regressions for the likelihood of being obese are estimated using various measures of the individual's neighborhood food options and walkability features.

Results show that indicators of neighborhood walkability--older neighborhoods, neighborhoods where a higher fraction of the population walks to work, and surprisingly neighborhoods with lower intersection density-- are associated with a lower BMI/obesity risk, although the strength of the effects varies by neighborhood income. The expected inverse relationship between the walkability indicator of population density and BMI/obesity risk is found only in low income neighborhoods.

We find a strong association between neighborhood retail food options and BMI/obesity risk with the magnitude of the effects again varying by neighborhood income. For individuals living in non-low income neighborhoods, having one or more convenience stores, full-service restaurants, or fast food restaurants is associated with reduced BMI/obesity risk, compared to having no neighborhood food outlets. The presence of at least one healthy grocery option in low income neighborhoods is also associated with a reduction in BMI/obesity risk relative to no food outlets. Finally, multiple food options within a neighborhood reduce BMI/obesity risk, relative to no food options, for individuals living in either low-income or non-low neighborhoods.

Key words: obesity, BMI, neighborhood walkability, food environment, Salt Lake City USA

Running to the Store? The Relationship between Neighborhood Environments and the Risk of Obesity

Introduction

The growing obesity epidemic in the United States (Flegal, Carroll, Ogden, & Johnson, 2002) has served as the catalyst for a spate of studies examining possible linkages between modifiable neighborhood features and the risk of residents being overweight and/or obese. The authors of these studies typically hypothesize that neighborhood characteristics are associated with an individual's body mass index (BMI) either because they affect residents' access to food options (i.e., energy intake) *or* because they alter residents' propensity to be physically active (i.e., energy expenditure). In this paper, we evaluate both dimensions. We also allow for differing effects in low income and non-low income neighborhoods with the aim of developing a more complete picture of the linkages between neighborhood characteristics and residents' BMI/obesity risk.

Local Food Environments

Previous research on the associations between local food environments and BMI has generally focused on the proximity of fast food outlets and/or full-service grocery stores and convenience stores (Burdette & Whitaker, 2004; Jeffery, Baxter, Mcguire, & Linde, 2006; Lopez, 2007; Maddock, 2004; Mehta & Chang, 2008; Morland, Roux, & Wing, 2006; Powell, Auld, Chaloupka, O'Malley, & Johnston, 2007; Powell, Chaloupka, & Bao, 2007; Rose & Richards, 2004; Rundle, Neckerman, Freeman, Lovasi, Purciel, Quinn et al., 2009; Simmons, McKenzie, Eaton, Cox, Khan, Shaw et al., 2005; Sturm & Datar, 2005; Wang, Cubbin, Ahn, & Winkleby, 2007a). Although most food outlets offer both healthy and unhealthy options, an observation that has guided this work is that full service restaurants and grocery stores typically offer healthier foods than fast food outlets and convenience stores (Sallis, Nader, Rupp, Atkins, & Wilson, 1986). However, a number of studies have found no association between the proximity of fast food outlets and BMI (Jeffery et al., 2006; Lopez, 2007; Simmons et al., 2005; Sturm, 2005; Sturm & Datar, 2005) while others have found a positive association (Maddock, 2004; Mehta & Chang, 2008; Rundle et al., 2009). Likewise, the smaller literature on proximity to large supermarkets versus small convenience stores is mixed with several studies reporting that access to a supermarket is associated with a lower risk of obesity (Lopez, 2007; Morland et al., 2006) or obesity related behaviors (Rose & Richards, 2004) while others have found no such relationship (Wang, Kim, Gonzalez, MacLeod, & Winkleby, 2007b).

It is not surprising that a clear consensus regarding the relationship between local food environments and BMI has not emerged. Researchers are often limited in how they measure access to the local food retailers by the availability of data. Geographic scales for food environment measures vary widely, including an individual's state (Maddock, 2004), county (Mehta & Chang, 2008), ZIP code (Lopez, 2007; Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007; Sturm & Datar, 2005), census tract (Morland et al., 2006; Morland, Wing, & Diez Roux, 2002), census block group (Wang, Gonzalez, Ritchie, & Winkleby, 2006; Wang et al., 2007b), or half-mile radius from the individual's residence (Rundle et al., 2009). Conceptually, the geographic unit should approximate the individual's shopping neighborhood (i.e., those destinations that s/he can get to within a reasonable time frame). Restricting prior studies to those that use a smaller geographic unit still yields conflicting results, however. Wang et al. (2007) find that closer proximity to a supermarket is linked to *higher* BMI in women, while Morland et al. (2006) report that the presence of a supermarket in a census tract is associated with a *lower* risk of overweight/obesity for men and women.

Prior work has also typically focused on one or two dimensions of the local food environment (e.g., proximity to fast food restaurants), which may lead to spurious findings if healthy or unhealthy food options tend to be clustered in the same geographic areas. Only two previous studies have included both grocery shopping options and options for purchasing meals away from home (Lopez, 2007; Rundle et al., 2009).

Neighborhood Walkability

A separate line of research has linked physical environments to health by examining the links between "walkable" neighborhoods and BMI. In these studies, design features of a neighborhood are measured in many different ways, with no consensus about a best measure in all circumstances. Studies at the neighborhood scale or larger typically include some combination of measures of the "3D's": population *density*, pedestrian friendly *design*, and a *diversity* of destinations (Cervero & Kockelman, 1997). As with the research on local food environments, the findings of these studies have produced mixed evidence on the relationship between neighborhoods that are expected to facilitate physical activity (e.g., walking, biking) and the risk of obesity.

Greater population density, which is hypothesized to be associated with the development of more walking destinations within a neighborhood, has been associated with fewer weight problems in many studies (Lopez-Zetina, Lee, & Friis, 2006; Lopez, 2004; Rundle, Roux, Freeman, Miller, Neckerman, & Weiss, 2007; Smith, Brown, Yamada, Kowaleski-Jones, Zick, & Fan, 2008; Stafford, Cummins, Ellaway, Sacker, Wiggins, & Macintyre, 2007; Vandegrift & Yoked, 2004) but not all studies (Frank, Andresen, & Schmid, 2004; Pendola & Gen, 2007; Ross, Tremblay, Khan, Crouse, Tremblay, &

Berthelot, 2007). Similarly, mixed results have been found in studies linking BMI to pedestrian-friendly neighborhood designs as measured by the density of intersections per area or the presence/quality of sidewalks (Boehmer, Hoehner, Deshpande, Brennan Ramirez, & Brownson, 2007; Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Frank et al., 2004; Giles-Corti, Macintyre, Clarkson, Pikora, & Donovan, 2003; Rundle et al., 2007; Smith et al., 2008). In addition, areas with broad mixes of land use are associated with lower weight in most (Frank et al., 2004; Mobley, Root, Finkelstein, Khaxjou, Farris, & Will, 2006; Rundle et al., 2007; Smith et al., 2008; Stafford et al., 2007; Tilt, Unfried, & Roca, 2007) but not all studies (Boehmer et al., 2007; Rutt & Coleman, 2005). A recent review shows stronger, more consistent relationships between obesity and neighborhood walkability and physical activity supports than between obesity and neighborhood food environments (Black & Macinko, 2008).

Part of the inconsistency may be related to variations in data availability, definitions of walkability, and geographic levels of analysis. Variables that capture key features of the walking environment within a local neighborhood are likely to provide good measures of individuals' the time-related travel choices (e.g., walking versus driving to the grocery store). Therefore, we examine walkability indicators at the level of the census block group or 1 km buffer when possible.

When measures of food environment are combined with walkability indicators, we argue that neighborhood food environment measures may also capture dimensions of land use diversity. Proximity to grocery stores, full-service restaurants, and even convenience stores and fast food outlets could increase an individual's energy output if residents walk to these facilities rather than drive to them. Proximity to food outlets might increase fruit and vegetable consumption if a nearby food outlet makes it convenient to purchase perishable but healthy foods more frequently. Alternatively, nearby unhealthy food options may make over-consumption more convenient as well. The presence of nearby grocery stores and full-service restaurants enhance healthy food options and reduce the time costs of using active modes of transportation (e.g., walking, biking) to purchase food. In contrast, the presence of local convenience stores and fast food outlets may not offer as many healthy food options but they do represent diverse walking/biking destinations within a neighborhood. Thus, the net impact of local food options on BMI may be unclear.

Low Income and Non-Low Income Neighborhoods and Obesity

Past research also reveals pervasive contextual effects of neighborhood economic status on the health of individuals (Macintyre, Ellaway, & Cummins, 2002; Pickett & Pearl, 2001). Low income neighborhoods may offer difficult conditions for both physical activity and healthy food consumption. Some researchers have emphasized how these neighborhoods are more likely to be "food deserts" or provide only unhealthy local food choices (Regan, Lee, Booth, & Reese-Smith, 2006). Those who sell healthy food may choose not to locate in low income neighborhoods or they may choose to stock there shelves with less healthy or more expensive food. Individuals in low income neighborhoods may not have the time or money resources to obtain healthy foods (Inagami, Cohen, Finch, & Asch, 2006) or crime and other incivilities in their neighborhoods may promote greater distress on the part of residents (Burdette & Hill, 2008; Ross & Mirowsky, 2001) which in turn could negatively affect eating behaviors. Similar restrictions may exist for physical activity resources (Papas, Alberg, Ewing, Helzlsouer, Gary, & Klassen, 2007). Consequently, we explicitly test to see if there are differences in the association between neighborhood characteristics and BMI in low income versus non-low income neighborhoods.

Our analysis contributes to the literature in several ways. First, we make use of data on neighborhood characteristics measured at the census block group level in an attempt to capture potentially important elements of the *local* environment. While most other research has measured neighborhood characteristics within larger geographic units (e.g., census tracts, ZIP codes, counties), we are able to gauge a range of local neighborhood features including food destinations that an individual can walk/bike to within a reasonable time frame from his/her home. Block groups are not necessarily the perfect geographic unit as in high density areas individuals may be very close to food sources that are in a different block group. Nonetheless, relative to other spatial units, block groups more closely approximate the local environment for an individual while they also contain important socioeconomic information unavailable at the block level.

Second, we operationalize the food environment measures in ways that test for food environment diversity effects. Specifically, we are able to compare and contrast BMI measures for individuals living in census block groups that lack retail food options, that have only one type of option, and that have multiple options.

Third, building on the work of Rundle et al. (2009), our analysis is only the second one to assess the relationship between the local food environment and BMI controlling for other walkable features in the neighborhood. Including both the food environment and neighborhood walkability measures increases our confidence that the relationships we observe are not simply spurious.

Finally, we allow for neighborhood effects to vary by the economic status of the neighborhood. This allows us to test the hypothesis that the relationship between BMI and environmental factors differs in low income and non-low income neighborhoods.

Methods

The Data

This study utilizes data from the Utah Population Database (UPDB). The UPDB is one of the world's richest sources of linked population-based information that focus on demographic, genetic, epidemiological, and public health outcomes. The UPDB contains 2005 driver license data from the Driver License Division (DLD) of the Utah Department of Public Safety. To protect confidentiality of driver license holders, all personal information from the Driver License Division was removed before the data were provided to the investigators on this research project. This project has been approved by the University of Utah IRB and the Utah Resource for Genetic and Epidemiologic Research. As part of this process, the UPDB staff retained identifying address information. They linked the driver license data (height, weight, gender, and age) to census-block groups via Universal Transverse Mercator (UTM) coordinates and then provided the researchers with a data set without individual addresses.

The current investigation assesses how adult BMI varies for residents of 566 block groups (one block group was dropped due to small sample size) from the 2000 Census for Salt Lake County, Utah, which had a total population of 898,387 in 2000. We use census block groups as the level of analysis for almost all of our area-level variables because block groups are relatively small areas (i.e., typically about 1,500 residents, ranging from 300 to 3000) (U.S. Census Bureau, 2000) that approximate local neighborhoods although variations naturally occur because some block groups are more densely populated than others.

Adults aged 25 to 64 years who have a driver license or driving privilege card with an address that can be geo-coded are included in the analyses. Based on U.S. Census figures (U. S. Bureau of the Census, 2008a), we calculate that 89.5% of the population age 25-64 in Salt Lake County have a geo-codable driver license or driving privilege card (i.e., the address on the license or privilege card can be mapped to an easting and northing location). Our data set contains no missing data once these restrictions are in place. We exclude young adults who have likely not established their post-adolescence residence and elderly adults for whom BMI is likely to have more complex associations with health (Bender, Jockel, Trautner, Spraul, & Berger, 1999; Reynolds, Saito, & Crimmins, 2005). We control for the effect of gender by simply including a dummy variable because preliminary analyses revealed no significant gender-specific interaction effects.

From the driver license data, height and weight information are converted to BMI (weight in kg/height in m^2) as well as categorical measures of overweight ($25 \leq$ BMI < 30) and obesity (BMI ≥ 30) in relation to healthy weight ($18.5 \leq$ BMI < 25). Once we exclude underweight individuals (BMI < 18.5) and individuals who are under age 25 or over age 64, the sample size is 453,927.

BMI data in the present study have the advantage of extensive coverage but the potential limitation of self-reported weight and a time lag between the physical environment and weight measures. These weight data likely share the limitations of self-reported weight in other studies, such as a tendency for individuals to underestimate their weight (Gorber, Tremblay, Moher, & Gorber, 2007; Nawaz, Chan, Abdulrahman, Larson, & Katz, 2001).

The UPDB driver license data represent each individual's most recent renewal. Renewals are required every 10 years or after address changes, name changes, or loss of license; thus the data represent the most recent height and weight data from 1995 through 2005. Given self-reported weight underestimation, the time lag between census and driver license data, and the fact that adults 25-64 typically gain weight over time (U.S. Department of Agriculture, 2005), the measures in this study are likely conservative estimates of any individual's current weight.

Driver license data provide individual-level age and sex. We do not have any other individual level measures such as education, income, or race in the UPDB. Block group census variables include neighborhood racial/ethnic composition (the proportion of the block group population that is Hispanic, African-American, Hawaiian/Pacific Islander, and Asian), median family income, and median age of individuals in the block group.

The UPDB data are linked to U.S. Census data that capture neighborhood walkability features. The block group measures of neighborhood walkability used in this study include population density and the fraction of the population who walk to work, both of which related to BMI in Smith et al. (2008). Density is measured as number of people per square mile in units of 1,000. Total land area in the block group is the denominator, making the density measure a less precise measure than if residential land area had been available for use. The fraction of people in the block group who walk to work is included as a crude measure of land use diversity. While walking to work is infrequent, it does indicate an area with some land use diversity given that home and work are within walking distance of each other for some. Both of these measures are taken from the 2000 U.S. Census.

Information on median age of houses in the neighborhood is not available at the block group level, so it is the one variable that is measured at the census tract level. Median housing age serves as one proxy for neighborhood walkability, as older neighborhoods have typically been designed with more walkable features (e.g., tree-shaded sidewalks, narrow streets) (Handy, 1996a; Handy, 1996b; King, Belle, Brach, Simkin-Silverman, Soska, & Kriska, 2005). For the 2000 Census, median age of houses is based on an item that is 'bottom-coded' for homes built in 1939 or earlier (i.e., all homes built before 1939 are in a single category). Pedestrian-friendly design is also measured by street connectivity as assessed by the number of intersections within a 1 km buffer of the resident's home. Street connectivity is derived from street data in the U.S. Census TIGER/Line file (U. S. Bureau of the Census, 2008b).

Finally, data on the local food environment obtained from spring 2008 Dun & Bradstreet files (Dun & Bradstreet, 2008) are linked to the UPDB. For each business, Dun & Bradstreet provide information on the business category using the U.S. Census Bureau's Standard Industrial Classification (SIC) codes along with its street address.

Food-related businesses in Salt Lake County were linked to census block groups based on address. These businesses were then grouped based on the SIC codes into four categories: healthy grocery options, full-service restaurants, convenience stores, and fast food restaurants.[2] We operationalize these measures of the local food environment through a series of dummy variables that capture whether or not an individual lives in a block group with only health grocery options, only full-service restaurant options, only convenience store options, only fast food options, or some combination of these four options. The omitted category in this sequence of dummy variables consists of those individuals living in block groups where there are no local food options, which comprises approximately 30 percent of the sample.

Statistical Methods

We evaluate how measures of the local food environment along with variables that capture the traditional 3D's (density, design, and diversity) relate to BMI and the odds of being obese in relation to having a healthy BMI. Linear regressions for BMI and logistic regressions for the likelihood of being obese are estimated. Parameter estimates associated with logistic regressions for overweight were very similar to the parameter estimates for obesity and thus for reasons of parsimony, we present only the obesity results here. Estimates for the risk of being overweight are available from the authors upon request. In addition, we estimate models with and without low income neighborhood interactions where low-income refers to block groups with median incomes in the bottom quartile of all block groups in the county. Statistical tests reveal that the models with the low income interactions are preferred and thus the discussion focuses on these estimates.

All estimation uses SAS software (PROC SURVEYREG and PROC SURVEYLOGISTIC). Analyses adjust for statistical dependence among observations induced by clustering of cases within block groups (Binder, 1983; Sarndal, Swenson, & Wretman, 1992). With these models, we report standard *p* values and 95 percent confidence intervals to represent the significance of the key variables. Given that this analysis is based on nearly the entire population, we recognize that the usual process of making statistical inferences about a population based on a sample may not apply here. Nonetheless, *p* values and confidence intervals provide valuable information about the ability of independent variables to help explain the variation in the dependent variables.

Results

Table 1 displays descriptive statistics. In Salt Lake County, 25 percent of adults age 25-64 who have driver licenses are obese. When focusing on residents of non-low income neighborhoods, the figure is slightly lower at 24 percent while in low income neighborhoods 28 percent are obese. These rates are slightly higher than the adult obesity rate for 2005-07 in Utah which is 21.8 percent (Trust for Healthy Americans, 2008). Our data are for only one county and we exclude the elderly, young adults, and those who are underweight, so these modest differences are not surprising. The age, income, and racial/ethnic composition reported in Table 1 mirror the figures reported for Salt Lake County in the 2000 Census.

[Insert Table 1 Here]

The traditional indicators of the neighborhood walkability suggest that Salt Lake County residents typically live in neighborhoods that are densely populated, with good street connectivity as measured by number of intersections, and where the housing stock is about 25 years old. Few residents in the 2000 Census reported walking to work. Individuals living in non-low income neighborhoods are more likely than individuals living in low income neighborhoods to reside in block groups with lower population density, fewer people who walk to work, and newer housing. Intersection density does not appear to vary by neighborhood income level.

Measures of the neighborhood food environment reveal that slightly less than one-third of adult drivers live in block groups where there are no retail food establishments. Another 28 percent live in neighborhoods where there is only one category of retail food establishment (e.g., one or more fast food restaurants, one or more full-service restaurants). Finally, 42 percent live in block groups with multiple retail food options. When the sample is divided into residents living in non-low income and low income neighborhoods, those living in non-low income neighborhoods are more likely than residents of low income neighborhoods to be in block groups with no retail food outlet or with only full service restaurants or fast food restaurants. They are also less likely than their counterparts living in low income neighborhoods to be in a block group where there are only convenience stores. Regression diagnostics reveal no problematic collinearity among the regressors that appear in Table 1.

Tables 2 and 3 reveal that features of the neighborhood physical environment are consistently associated with BMI and obesity risk in both low income and non-low income neighborhoods. But, while the directions of the effects are the same in both equations, the magnitudes of these effects differ significantly across the two groups. An increase in population density is associated with a significant reduction in BMI and obesity risk in both low income and non-low income neighborhoods but the magnitude of the effect is greater in low income neighborhoods. The same is true for the percentage of workers who walk to work. In contrast, older housing stock within a neighborhood is associated with a significantly larger decrease in BMI and obesity risk in non-low income neighborhoods than in low income neighborhoods. Similarly, an increase in the number of intersections is associated with an increase in BMI and obesity risk, but the magnitude of this positive effect is significantly greater in non-low income neighborhoods than in low income neighborhoods.

[Insert Tables 2 & 3 Here]

Tables 2 and 3 also reveal intriguing differences in the relationships among characteristics of the local food environment, neighborhood income, and BMI or obesity risk. For individuals living in non-low income neighborhoods, having one or more convenience stores, full service restaurants, or multiple retail food options, all reduce BMI and the risk of being obese, in comparison to having no retail food options in a neighborhood. Interestingly, residents of non-low income neighborhoods where there are only healthy grocery shopping options or only fast food options are not significantly different in their BMI/obesity risk from their counterparts who live in neighborhoods with no retail food options. In contrast, residents of low income neighborhoods have significantly lower BMIs and lower risks of being obese if there is one or more healthy grocery shopping options within their block group relative to residents who live in block groups with no retail food options. A benefit of having one or more convenience stores or full-service restaurants was found in non-low income areas but not in low income neighborhoods. The benefit of having multiple retail food options in the block group is associated with a reduction in BMI and obesity risk of similar magnitude in both low income and non-low income neighborhoods.

The magnitude of the statistically significant effects noted in Tables 2 and 3 also merits comment. At first glance, the absolute effects appear small. But, when they are viewed in the contexts of the units of observation for the independent variables their potential impact increases. For instance, multiple food options are associated with a 10% reduction in the odds of an individual in a non-low income neighborhood being obese and an 8% reduction in the odds for low income residents being obese. When such effects are viewed in the context of the entire population of 25-64 year olds in Salt Lake County, these influences are considerable.

Discussion and Conclusions

Crucial to the study of the relationship between neighborhood environments and BMI is the geographic definition of neighborhood. In this study, neighborhoods are defined in relatively narrow geographic terms in order to capture immediate local walkability. Our findings suggest that local neighborhood environments matter.

We find support for the traditional measures of the 3D's with population density, neighborhood age, and walk-to-work measures being inversely related to BMI and obesity risk consistent with some past studies (Lopez-Zetina et al., 2006; Lopez, 2004; Rundle et al., 2007; Smith et al., 2008; Stafford et al., 2007; Vandegrift & Yoked, 2004). But, we also find that the magnitude of all of these effects differs significantly by neighborhood income, suggesting that neighborhood design interventions geared at reducing obesity risk might be more effective if they are tailored to the residents' socioeconomic circumstances.

The estimated relationship between intersection density and BMI/obesity risk, although significant, is counter to the hypothesis that greater street connectivity should be associated with lower BMI. It may be that greater street connectivity reflects greater car traffic, all other things held constant, that would discourage individuals from using active forms of transportation such as walking or biking. In addition, Salt Lake City has unusually wide streets and this might also discourage walking in block groups with more intersections. Unfortunately, testing these propositions is beyond the scope of our investigation.

We find mixed support for neighborhood diversity as measured by characteristics of the local food environment. Consistent with much of the past research (Jeffery et al., 2006; Lopez, 2007; Simmons et al., 2005; Sturm, 2005; Sturm & Datar, 2005), our analyses find no relationship between proximity to fast food outlets and BMI/obesity risk. However, building on the findings of Lopez (2007) and Morland et al. (2006), we do observe a significant relationship between the presence of healthy grocery stores and reduced BMI/obesity risk in low income neighborhoods.

The presence of healthy grocery options in the immediate neighborhood may reduce the time costs of making healthy food purchases for low income individuals who are more likely to rely on public transportation and/or walking/biking for groceries, or they may reduce the time costs of making multiple supermarket trips for healthy but perishable foods. This finding represents a case where access to a healthy food option within one's neighborhood may provide the greatest benefits to the most vulnerable.

For individuals living in non-low income neighborhoods, the presence of healthy grocery options is not associated with lower BMI or a reduced risk of being obese, compared with no food options. Individuals living in these neighborhoods may be more likely to rely on automobile transportation to do their major grocery shopping given that one often has numerous bags to carry. If so, these individuals may be less constrained by neighborhood options and thus the presence of healthy grocery options would have little impact on their BMI or risk of obesity.

The differential importance of the local food environment for individuals living in low income neighborhoods is also revealed by shifts in the relationships between BMI/obesity risk and the presence of only full-service restaurants in the local area. While full-service restaurants are linked to lower BMI for individuals in non-low income neighborhoods, the relationship disappears for individuals in low income neighborhoods. This difference may be attributable to the fact that individuals living in low income neighborhoods are less likely to have the financial resources to eat at full-service restaurants.

We hypothesize that multiple food options in a neighborhood increases the diversity of walkable destinations within a reasonable time frame and thus, residents living in such neighborhoods would have lower BMIs relative to those living in neighborhoods with no retail food options. This hypothesis is confirmed although the magnitudes of the multiple food option coefficients are generally smaller than those associated with other neighborhood retail food configurations. “Multiple retail food options,” however, is the one independent variable that has statistically significant coefficients for both the low income neighborhood and non-low income neighborhood equations that are *not* significantly different from one another. Thus, it appears that individuals living in both low income and non-low income neighborhoods benefit equally from having diverse retail food options in their block groups.

The question of why food environment effects vary by neighborhood income level merits further investigation. It may be that differential access to transportation heightens the importance of the immediate food environment for individuals living in low-income neighborhoods. It is also plausible that our measures of the food environment are serving as proxies for neighborhood disorder (e.g., multiple food options representing lower levels of disorder). Prior research (Burdette & Hill, 2008; Ross & Mirowsky, 2001) has found that individual health is inversely related to the degree of neighborhood disorder. If the presence of multiple food options represents lower levels of disorder, then we may be detecting disorder effects rather than walkability effects in the current analyses. Unfortunately, these alternative hypotheses cannot be tested with our data.

Our findings are circumscribed by several caveats. Specifically, self-reported BMI can systematically underestimate true BMI. Likewise, while the use of census block groups as the geographic unit improves upon the larger geographic units used in many previous studies, there is still the possibility of measurement error in classifying residents' proximity to retail food establishments. In addition, neighborhood environment measures available in the census are only proxies of local neighborhood density, diversity, and design. Finally, our data include only the 89.5% of Salt Lake County residents between the ages of 25 and 64 who have a driver license or driver privilege card. Those excluded from our sample may be the most economically disadvantaged who may be at a higher risk of being obese. All of these study limitations make our findings conservative.

Other research constraints in the current study have potential ambiguous effects on our findings. First, few individual measures are available in the UPDB. Thus, other potential controls (e.g., number of years in the neighborhood, individual race/ethnicity, individual income, individual education) could not be included in the analyses. As such, our analysis reflects associations between neighborhood characteristics and BMI/obesity risk but they do not imply causality. Second, our study is based on one (albeit large) county. It will be important to replicate these findings in other locales. Finally, because the analysis is cross-sectional, it is possible that those who value healthy weight may move to walkable neighborhoods. Future work should address all of the above limitations.

Our paper provides some "food-for-thought" for policymakers and urban planners interested in reducing obesity risk. By 2030 almost half the buildings in the U.S. will have been built since 2000 (Nelson, 2004), creating opportunities for evidence-based health data to inform community design. Planners who have embraced new urbanism models advocate community designs that emphasize mixed land use, increased density, and mixed housing (2008). The current analyses suggest that these new urbanist designs may well serve to reduce obesity risk.

In existing neighborhoods, policymakers concerned with reducing obesity risk have recently begun to argue for novel policies such as imposing a moratorium on the building of fast food restaurants (Hennessy-Fisk, 2008) or directing public funds to grocers in low-income areas so that they might expand their offerings of fresh produce (2006). While our results suggest that fast food outlet restriction policies may not be effective, initiatives that increase neighborhood food options may be effective in reducing individuals' obesity risks, especially if these efforts are focused on low-income neighborhoods.

Endnotes

1. Healthy grocery options include SIC codes for grocery stores, supermarkets, supermarket chains, cooperative food stores, meat and fish markets, fish markets, seafood markets, meat markets, fruit and vegetable markets, fruit stands, vegetable stands, dairy products stores, and milk, cheese, and butter stores. Convenience stores include both chain and independent convenience stores as noted by the SIC codes. Full service restaurants include SIC codes for all ethnic restaurants, coffee shops, delicatessens, grills, cafeterias, luncheonettes, lunch counter restaurants, family restaurants, seafood restaurants, barbecue restaurants, steak restaurants, buffets, commissary restaurants, health food restaurants, and diners. Fast food restaurants include SIC codes for fast food restaurant chains, independent fast food restaurants, pizza chains, independent pizzerias, drive-ins, carry-out only restaurants, box lunch stands, soft drink stands, soda fountains, ice cream/frozen yogurt stands, and concessionaires.

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Table 1. Descriptive Statistics

	Full Sample (N=453,927)		Non-Low Income Neighborhood Residents (N=340,466)		Low Income Neighborhood Residents (N=113,461)	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Socio-Demographic Measures						
BMI	25.84	4.85	25.75	4.77	26.10	5.07
Proportion BMI$\geq$30	.25		.24		.28	
Proportion Women	.47		.48		.43	
Individual's Age	41.36	11.01	41.98	11.01	39.51	10.80
Median Family Income in BG[a] ($10,000s)	57.20	19.53	64.45	16.96	35.42	5.56
Proportion African American in BG	.01		.01		.02	
Proportion Hawaiian/ Pacific Islander in BG	.01		.01		.02	
Proportion Hispanic in BG	.12		.08		.23	
Proportion Asian in BG	.03		.02		.03	
Median Age in BG	29.44	5.35	29.59	5.62	29.00	4.40
Physical Environment Measures						
Population Density/Sq. Mile in BG	5,396	3,070	4,875	2,604	6,959	3,757
Proportion of Workers Who Walk to Work in BG	.02		.01		.04	
Median Age of Housing in Years in Census Tract	25.21	15.35	22.32	14.51	33.88	14.50
Intersections within sq. km. of Residence	40.65	18.54	40.06	18.39	42.43	18.86
Food Environment Measures[b]						
Healthy Grocery Options Only in BG (1=yes)	.04		.04		.05	
Convenience Food Stores Only in BG (1=yes)	.03		.02		.07	
Full Service Restaurants Only in BG (1=yes)	.14		.15		.10	
Fast Food Restaurants Only in BG (1=yes)	.07		.08		.05	
Multiple Food Options in BG (1=yes)	.42		.39		.50	

[a] BG=Block Group

[b] The omitted group in this sequence of dummy variables are those people living in block groups with no retail food establishments (.30 in the full sample, .32 in non-low income neighborhoods, and .23 in low income neighborhoods).

Table 2. Parameter Estimates of Regression Analyses of BMI for Individuals Aged 25-64[a]

	Full Sample		**Non-Low Income Neighborhood Residents**		**Low Income Neighborhood Residents**		**T-Tests for Coefficient Differences**[b]
	Coefficient (t statistic)	**95% CI P Value**	**Coefficient (t statistic)**	**95% CI P Value**	**Coefficient (t statistic)**	**95% CI P Value**	
Physical Environment Measures							
Population Density (1,000's)/Sq. Mile in BG	-.02	(-.03) – (-.02) <.01	-.00	(-.01) – (.00) .43	-.04	(-.05) – (-.00) <.01	-4.86**
% of Workers Who Walk to Work in BG	-3.76	(-4.25) – (-3.27) <.01	-2.29	(-3.10) – (-1.48) <.01	-4.92	(-5.57) – (-4.27) <.01	-5.65**
Median Age of Housing in Years in Census Tract	-.01	(-.02) - (-.01) <.01	-.02	(-.02) – (-.01) <.01	-.01	(-.01) – (-.00) <.01	5.30**
Intersections within sq. km (10's)	.10	.(09) – (.12) <.01	.08	(.01) – (.01) <.01	.02	(.00) – (.00) <.01	-4.53**
Food Environment Measures							
Healthy Grocery Options Only in BG	-.16	(-.23) – (-.09) <.01	-.05	(-.13) – (.03) .24	-.26	(-.41) – (-.10) <.01	-2.30**
Convenience Food Stores Only in BG	-.25	(-.33) – (-.17) <.01	-.30	(-.40) – (-.20) <.01	-.02	(-.15) – (.10) .70	3.10**
Full Service Restaurants Only in BG	-.19	(-.24) – (-.15) <.01	-.24	(-.29) – (-.19) <.01	-.08	(-.18) – (.03) .16	2.70**
Fast Food Restaurants Only in BG	-.03	(-.09) – (.02) .26	-.06	(-.12) – (.01) .07	.10	(-.05) – (.24) .20	1.53
Multiple Food Options in BG	-.17	(-.20) – (-.13)	-.17	(-.22) – (-.14) <.01	-.13	(-.21) – (-.06) <.01	.81
Neighborhood Income <25%tile	.21	(.16) – (.25) <.01	---	---	---	---	---
Adjusted R^2	.08		.09		.06		

[a] These multivariate analyses control for the ethnic/racial composition of the block group, the median age of the block group, the individual's age, and the individual's gender.

[b] These t-tests were based on a single multivariate model where neighborhood income category was interacted with all of the neighborhood environment variables.

Table 3. Odds Ratios of the Risk of Being Obese Relative to Healthy Weight Individuals, Age 25-64[a]

	Full Sample		Non-Low Income Neighborhood Residents		Low Income Neighborhood Residents		χ^2 Tests for Differences[b]
	Coefficient	**95% CI P Value**	**Coefficient**	**95% CI P Value**	**Coefficient**	**95% CI P Value**	
Physical Environment Measures							
Population Density (1,000's)/Sq. Mile in BG	.98	.98-.98 <.01	.99	.99-1.00 .24	.97	.96-.98 <.01	16.60**
% of Workers Who Walk to Work in BG (.025)	.94	.93-.95 <.01	.95	.94-.97 <.01	.93	.92-.94 <.01	8.75**
Median Age of Housing in Years in Census Tract (10's)	.92	.91-.93 <.01	.91	.90-.92 <.01	.95	.94-.96 <.00	20.82**
Intersections within sq. km (10's)	1.06	1.06-1.07 <.01	1.05	1.04-1.06 <.01	1.02	1.01-1.03 <.01	11.62**
Food Environment Measures							
Healthy Grocery Options Only in BG	.92	.83 - .92 <.01	.99	.95 – 1.05 .87	.86	.79 - .94 <.01	7.73**
Convenience Food Stores Only in BG	.87	.83 - .92 <.01	.85	.79 - .91 <.01	.99	.91 – 1.06 .70	7.55**
Full Service Restaurants Only in BG	.89	.87 - .92 <.01	.86	.83 - .89 <.01	.98	.92 – 1.04 .51	11.24**
Fast Food Restaurants Only in BG	.98	.95 – 1.02 .29	.96	.92 – 1.00 .07	1.06	.98 – 1.16 .15	3.20
Multiple Food Options in BG	.90	.89 - .92 <.01	.90	.87 - .92 <.01	.92	.88 - .96 <.01	.38
Neighborhood Income <25%tile	1.12	1.09 – 1.15 <.01	---	---	---	---	---
χ^2	24,040		20,442		4,828		

[a] These multivariate analyses control for the ethnic/racial composition of the block group, the median age of the block group, the individual's age, and the individual's gender.
[b] These χ^2 tests were based on a single multivariate model where neighborhood income category was interacted with all of the neighborhood environment variables.