THE LOCAL FOOD ENVIRONMENT AND ITS ASSOCIATION WITH OBESITY AMONG LOW-INCOME WOMEN ACROSS THE URBAN-RURAL CONTINUUM IN KANSAS

by

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B.S., Clemson University, 1987
M.S., University of Georgia, 1990

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Human Nutrition
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Abstract

The prevalence of obesity within the U.S. has risen dramatically in the past thirty years. Recent changes in food and physical activity environments may contribute to increased obesity prevalence, suggesting that disparities in these environments may be linked to the increased risk of obesity observed in low-income, and racial/ethnic minority women. This dissertation characterizes the local food environment experienced by low-income women who participate in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) in Kansas, evaluates whether characteristics of the local food environment contribute to obesity risk, and examines how these relationships vary across the urban-rural continuum.

Chapter One reviews the relevant literature examining the association between obesity and local food environments, and identifies three testable hypotheses that serve as the framework for later chapters. Chapter Two characterizes the local food environment and examines geographic, racial, ethnic, and socioeconomic disparities in the availability of small grocery stores and supermarkets. Chapter Three examines the association between store availability and obesity risk at an individual level among participants in the WIC Program, while Chapter Four utilizes multi-level modeling to examine the relationships between tract deprivation, tract store availability and body mass index (BMI).

Significant geographic disparities were observed in the availability of small grocery and supermarkets. Racial and ethnic disparities observed within tracts were not observed when examining store availability in a 1-mile radius around the residence of WIC mothers. The majority of women participating in the WIC program resided within a 1-mile radius of a small grocery store, and micropolitan and metropolitan WIC mothers had a multiplicity of food stores available within a 3-mile radius of residence. Food store availability was associated with increased obesity risk only in micropolitan areas. The availability of food stores did not mediate the association between tract deprivation and BMI, which varied across the urban-rural continuum. Overall, these results suggest that the relationship between local food environments and eating behaviors is complex, that

limited store availability does not contribute to increased obesity risk in vulnerable populations, and that the association between local food environments and obesity risk varies across the urban-rural continuum.

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Dedication

To Bill and Paul – in deep appreciation and gratitude for your steadfast love and support

Dissertation Introduction

The prevalence of obesity has increased dramatically in the past 30 years, with approximately 30% of American adults currently classified as obese [1]. This rapid increase has significant implications for public health, because obesity is associated with increased risk for many other diseases, including high blood pressure, high blood cholesterol, type 2 diabetes, and coronary heart disease [2]. While the prevalence of obesity has increased among all sociodemographic groups, obesity rates among low-income and racial/ethnic minority women are significantly higher than their more affluent and white counterparts [3].

There is a growing consensus that such dramatic increases in the prevalence of obesity are unlikely to be attributable to changes in individual level characteristics of the population, but are instead associated with population-level changes in the food and physical activity environment [4-8]. Socioecological models of health behavior suggest that neighborhood or community context play an important role in influencing eating and physical activity behaviors associated with obesity [9]. Within socioecological models, the neighborhood is understood to be a geographic area with shared physical, social, and economic characteristics, in which individuals interact [10]. The availability of supermarkets and other stores that provide healthy food options are an important component of the neighborhood built environment that can influence dietary behaviors and outcomes [4, 7].

Recent research suggests that there are significant geographic, socioeconomic, racial and ethnic disparities in the availability of supermarkets in low income and high minority neighborhoods [11-13]. However, evidence of the association between supermarket availability and obesity is mixed. While some research reports that the presence of a supermarket within a neighborhood is protective against obesity and weight gain [14-16], other studies report that increased neighborhood availability of supermarkets and small grocery stores is associated with an elevated risk of obesity [17]. Potential reasons for the inconsistency in results include differences in the assessment of supermarket and grocery store availability, differences in residential segregation patterns, and potential confounding associated with other neighborhood level characteristics. Tract deprivation, a composite variable incorporating multiple dimensions of socioeconomic status within a census tract, is also a confounding factor that is often unexamined when the association between store availability and obesity is investigated. It is important to gain a better understanding of the complex relationships between supermarket availability, dietary patterns, and risk of obesity in order to inform, understand and design multilevel interventions to address obesity in vulnerable populations.

The primary aim of this dissertation is to examine the association between the local food environment and obesity among low-income women across the urban-rural continuum. To achieve this aim, this dissertation is organized into four chapters, including three chapters that investigate specific aspects of the food environment and obesity using a large, surveillance dataset of low-income women who participated in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Although these chapters are interrelated, each chapter has distinct hypotheses, and provides important insight for understanding the relationship between local food environments and obesity across the urban-rural continuum.

The primary aim of Chapter One was to review the literature on the association between retail food access and obesity. This literature review was organized by hypothesis, and identifies three specific hypotheses linked to the central question of whether disparities in obesity prevalence are due to variations in the retail food environment.

The primary aim of Chapter Two was to examine geographic, racial, ethnic and socioeconomic disparities in the availability of supermarkets and small grocery stores across the urban-rural continuum in Kansas. The secondary aim of this chapter was to examine whether estimates of store availability and observed associations between individual sociodemographic characteristics differed when examining availability within a 1-mile radius of residence as compared to those obtained when examining availability and observed associations at a census tract level. In order to achieve this aim, the home residence of WIC mothers was geocoded and combined, within a geographic information system (GIS), with a geo-referenced dataset of licensed food retail stores. These datasets permitted us to examine availability of supermarkets and to test whether there were disparities in the availability of supermarkets among low-income women across the urban-rural continuum in Kansas.

The third chapter utilized the same geo-referenced datasets to test whether the presence of a supermarket, small grocery store, or convenience store was associated with reduced risk of obesity among women who participated in the WIC program in Kansas, and to determine whether the association between store availability and obesity varied across the urban-rural continuum.

Chapter Four utilized multi-level modeling to examine the associations between tract deprivation, supermarket availability and BMI among WIC mothers in Kansas. Specifically, we explored whether tract deprivation was associated with increased BMI among WIC participants, and whether this association was moderated by urban influence. The secondary aim of Chapter 4 was to determine whether supermarket or small grocery store availability mediated the association between tract deprivation and BMI in low-income women.

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CHAPTER 1 - Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses

Although the overall population in the United States has experienced a dramatic increase in obesity in the past 25 years, ethnic/racial minorities, and socioeconomically disadvantaged populations have a greater prevalence of obesity, as compared to white, and/or economically advantaged populations. Disparities in obesity are unlikely to be predominantly due to individual psychosocial or biological differences, and they may reflect differences in the built or social environment. The retail food environment is a critical aspect of the built environment that can contribute to observed disparities. This paper reviews the literature on retail food environments in the United States and proposes interrelated hypotheses that geographic, racial, ethnic, and socioeconomic disparities in obesity within the United States are the result of disparities in the retail food environment. The findings of this literature review suggest that poor-quality retail food environments in disadvantaged areas, in conjunction with limited individual economic resources, contribute to increased risk of obesity within racial and ethnic minorities and socioeconomically disadvantaged populations.

Introduction

Prevalence of overweight (BMI $\geq$25 kg/m^2) and obesity (BMI $\geq$30 kg/m^2) has increased dramatically in the United States in the past 25 years, with recent surveys reporting approximately 23% of adults categorized as obese.[1] Among children and adolescents, the prevalence of overweight has increased even more dramatically, having almost tripled since 1980.[2] While most international obesity rates are not as high as those reported in the United States, similar trends have been reported in other industrialized countries.[2, 3]

Although overweight and obesity has increased across almost all racial, ethnic and socioeconomic levels, there are significant disparities within the overall US population, with higher BMIs associated with socioeconomic disadvantage and non-white race and ethnicity.[2, 4-6] Employing multivariate regression techniques on reported height and weight data from the 2000 National Health Interview Study, Denney et al.[4] identified disparities in relative risks associated with overweight and obesity that persisted even after controlling for sex, age, marital status, region, family income, education, employment, smoking, biking/walking habits, and weekly vigorous activities. The relative risk ratios and confidence intervals (CIs) for overweight among various racial/ethnic groups were as follows: 1.60 (95% CI, 1.44–1.76) for non-Hispanic blacks; 2.14 (95% CI, 1.32–3.47) for Native Americans; 0.5 (95% CI, 0.40–0.61) for Asian Americans; 1.21 (95% CI, 0.93–1.58) for Puerto Ricans; 1.54 (95% CI, 1.36–1.76) for Mexican Americans; and 1.57 (95% CI, 2.16–2.45) for Cuban Americans. It is important to note, however, that when stratified by sex, disparities by race and ethnicity are more consistently observed among women, as compared to men.[4, 7-9] Disparities in obesity prevalence by race and ethnicity that persist even after controlling for socioeconomic position have been reported elsewhere.[5, 6, 10-12]

Low socioeconomic status (SES) has also been independently associated with increased risk for obesity in industrialized countries, particularly in women. In a recently published review of the literature on SES and obesity, McLaren[9] identified inverse associations between SES and obesity among women in 63% in cross-sectional studies conducted in industrialized countries. In contrast, the pattern of association between SES and obesity was less consistent among men in industrialized countries, with a general pattern of non-significance or curvilinearity with most socioeconomic indicators (income, material possessions and occupation) and an inverse association with other socioeconomic indicators (education).

The central proximal causes for racial, ethnic, and socioeconomic disparities in the prevalence of obesity have traditionally been attributed to individual differences in health behaviors influencing calorie balance. Specifically, health behavior research in this area has found racial/ethnic, and socioeconomic differences in physical activity,[13] fresh fruit and vegetable consumption,[14] and dietary fat intake.[15] However, social ecological theory suggests that individual health decisions are determined by multiple levels of influence, including institutional, community, and broader physical, economic, and cultural environmental levels.[16] Recent attention to the contribution of built environments to obesity ("obesogenic environments") has led to the development of several frameworks for empirically describing retail food environments with respect to the availability, accessibility and pricing of foods associated with healthy eating behaviors.[17-21] These models identify environmental variables hypothesized to influence eating behaviors at the contextual level, a critical prerequisite for systematically examining nutrition environments using multilevel models that include information gathered at both the individual level and the environmental level.

The present report proposes three hypotheses that can serve as a framework for empirically testing the association between neighborhood retail food environments and obesity, and for examining the role environmental disparities may play in the prevalence of obesity among different racial/ethnic and socioeconomic groups within the United States. The proposed hypotheses to be tested include: 1) geographic differences in the access and availability of foods result in disparities in the retail food environment; 2) neighborhoods of low SES with high concentrations of racial/ethnic minorities have limited accessibility to and availability of healthy foods (poor-quality retail food environment), as compared to neighborhoods of relatively high SES and low concentrations of ethnic/racial minorities; and 3) individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density and to have higher rates of obesity, as compared to individuals exposed to high-quality food environments.

To provide preliminary evidence to test these hypotheses, a PubMed (National Library of Medicine, Bethesda,Maryland) search was conducted for the period 1992–2007 using the search terms "food environment", "nutrition environment", "food access", "food availability", and "obesity". Studies found through the electronic search were supplemented with others that were brought to our attention through the literature review. Abstracts of selected papers were screened and the study was included in the review if it was conducted in the United States and included a characterization of the retail food environment. Of the 13 studies included in the review, six employed an ecological research design, four used a cross-sectional approach, and three were multilevel studies. The studies are organized and discussed by hypothesis, and summarized in Tables 1–3.

Hypothesis 1

Geographic differences in the access and availability of foods result in disparities in the retail food environment.

The question of whether food environments differ geographically has been addressed by several investigations in a host of disciplines.[22-25] It is important to note, however, that differences in the retail food environment do not always represent disparities. Consistent with the definition of health disparities as outlined by Braveman[26], disparities in the food environment refer to avoidable differences in the access and availability of healthful foods that systematically place socially disadvantaged groups at a further disadvantage for achieving healthy diets. Although it has been well documented that there are regional variations associated with food preference and price among ethnic groups and by region, disparities in retail food environments across neighborhoods are not well understood. However, observational measures of the quality of retail food environments, as characterized by availability, accessibility, and pricing, provide a useful method for comparing food environments between neighborhoods. A selective summary of recent research examining geographic differences in retail food environments using observational measures is presented in Table 1.

First introduced as a concept to examine disparities in food access and pricing in the United Kingdom, the term “food desert” has been used to describe areas with limited access to retail grocery stores.[27] Early research on food deserts was primarily concerned with exploring the impact of retail flight from the urban core, but it has since been extended to include rural areas that have experienced reductions in populations and concomitant reductions in the retail sector, including small-town supermarkets.[28-30] Research in this area examined the availability of supermarkets by store type (supermarket chain versus small grocer or convenience store) and pricing differentials among stores.[27, 31] Of the four studies identified in this review (Table 1), there is relatively consistent evidence that the quality of the retail food environment (as measured by access and availability of healthy foods) varies geographically, and that low-quality food environments are associated with neighborhood deprivation. This contrasts with recently reported food-environment studies from the United Kingdom in which the association between the quality of the food environment and the sociodemographic structure of the neighborhood is mixed,[32] casting some doubt on the existence of "food deserts" within the United Kingdom.[30, 33, 34] While some of the variance associated with the relationship between retail food environment and neighborhood demographics in the United States and the United Kingdom can be linked with different patterns of residential segregation among countries, additional sources of variance may be associated with Modifiable Areal Unit Problems (MAUP) in which both scale and zoning influence the relationships being tested.[32, 34, 35] Nevertheless, results pairing reduced access and higher prices have been noted by other researchers in the United Kingdom,[36-38] Canada,[39] and the United States.[40-44] Regardless of whether or not one adopts the "food desert" terminology, most research within the United States supports the hypothesis that there are disparities in the retail food environment that can be identified at the neighborhood level.[45]

Hypothesis 2

Neighborhoods of low socioeconomic status with high concentrations of racial/ethnic minorities have limited accessibility and availability of healthy foods (poor-quality retail food environment).

The association between neighborhood racial, ethnic, and socioeconomic profile and food availability has been studied extensively within a variety of contexts and utilizing a number of different research techniques. A summary of recent research on the association between neighborhood-level characteristics and retail food environments is presented in Table 2.

Zenk et al.[46] used Geographic Information Systems (GIS) to examine the impact of racial and economic segregation on access to supermarkets in metropolitan Detroit, Michigan. They reported that socially disadvantaged neighborhoods comprised primarily of African Americans were, on average, 1.1 miles further from the nearest supermarket compared to predominantly white neighborhoods within the same socioeconomic classification. Baker et al.[47] also employed GIS to determine spatial distribution and clustering of supermarkets and fast-food outlets in St. Louis, Missouri. They found that mixed-race or white high-poverty areas were significantly less likely to have access to foods that enable adherence to a healthy diet, as compared to predominantly white, higher income areas. As in the Detroit study, residents in African American neighborhoods had significantly less access to supermarkets and other retail sources with 'healthier' foods, regardless of income, as compared to predominantly white neighborhoods.

Similar results were reported by Moore and Diez Roux[48] in an investigation of the association of neighborhood characteristics with location and type of food stores in selected census tracks participating in the Multiethnic Study of Atherosclerosis. In their study, which included sites in North Carolina, Maryland, and New York, predominantly minority and low-income neighborhoods had significantly fewer supermarkets as compared to predominantly white and higher income communities, even after adjusting for different population densities across all sites. While there were significant differences in food environments (as measured by food store type) among the three sites studied, the finding that larger supermarkets were more prevalent in higher income and predominantly white areas has significant implications with respect to the availability of healthy foods, since supermarkets traditionally carry a larger array of food items.[21]

Although there is relatively strong evidence supporting the association of disparate retail food and nutrition environments among neighborhoods of differing SES and racial/ethnic profile in the United States, it is important to note that the methods employed in these studies influenced the strength of the relationship between neighborhood sociodemographics and food environments. Those studies that included direct observation of food environments using market-basket analysis[36, 43, 47, 49] tended to show that the relationship between availability, pricing, and access to healthy foods was complex, and the association between neighborhood-level characteristics and food environment tended to be weaker, especially for pricing variables. Studies that utilized store type as a proxy for access to healthy foods[44, 48] generally found a relatively strong association between neighborhood characteristics and food environment. There are clear trade-offs when contrasting the two methods: the use of store type as an indicator of access and price associated with healthy foods allows larger and more diverse retail food environments to be studied feasibly; it is also supported by the strong associations found in the literature between store types, food availability, and food prices.[41, 50-53] However, direct observation of food and nutrition environments (including market-basket analysis techniques) may allow for critical differences in quality to be noted, although variations in market-basket composition limit the ability to generalize results.

Despite these variations in research methods, there are consistent trends among results from studies conducted in the United States. Whether using objective approaches that measure the specific foods available or proxy measures looking solely at food-store type, there is an association in which socioeconomically disadvantaged neighborhoods with high proportions of racial and ethnic minorities have poorer quality retail food environments, as measured by access to and availability of healthy foods, compared to more affluent areas with comparatively small populations of ethnic and racial minorities.

It is imperative, however, to recognize the limitations of these studies with respect to understanding the causal linkage between food environments and obesity. Foremost, eating behaviors are influenced by a multitude of environmental factors operating at different levels of organization; these are mediated by psychosocial, demographic, and sociocultural factors that operate at the individual level. Although some research indicates that the availability of supermarkets (which stock a greater quantity and variety of fruits and vegetables) is associated with greater adherence to recommended dietary practices at an individual level,[51, 54-56] larger-scale and longitudinal studies using individual-level data, in conjunction with environmental data (beyond access and availability), are needed to further refine our understanding of the relationships among food access, availability, and obesity. As highlighted in hypothesis 3 of this paper, multilevel studies offer significant advantages for understanding the relationships among individual food behaviors, food access and availability, and obesity.

Hypothesis 3

Individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density, and higher rates of obesity, as compared to individuals exposed to high-quality food environments.

As highlighted in the studies reviewed above, a number of characteristics associated with the retail food environment (access, availability, and price) have been reported to differ significantly according to neighborhood socioeconomic and demographic characteristics. These differences parallel trends in which low SES and non-white race and ethnicity is associated with higher prevalence of obesity, particularly in women.[8, 57] Although these studies suggest that the quality of retail food environments on a neighborhood level affect eating patterns at an individual level, their observational and cross-sectional design limit any causal inferences on the relationships among food environment, food choices, and obesity. Multilevel studies that permit the delineation of individual (compositional) from neighborhood (contextual) effects, hold promise for facilitating greater understanding of the role of retail food environments in promoting food choices associated with healthy eating patterns.

Morland et al.[42, 58] utilized food-frequency data from individuals participating in the Atherosclerosis Risk in Communities (ARIC) study (n=10,623) to estimate food intake at the individual level. This study found that the availability of supermarkets varied significantly by race, with five times more supermarkets located in census tracts in which whites dominated the population. More importantly for the purposes of exploring the impact of retail food availability on food intake, African Americans living in the same census tract with a supermarket were more likely to meet the dietary guidelines for fruit and vegetable consumption, a relationship that exhibited a dose-response effect with each additional supermarket located within their census tract. The resulting increase in fruit and vegetable consumption associated with availability corresponded with an average increase of 32% in fruit and vegetable consumption for each additional supermarket. While the inclusion of other food store types (grocery stores and restaurants) into the model had a slight effect on reported dietary intake, the effect was less clear and non-significant for fruit and vegetable intake. Interestingly, the significant protective effect of living within the same census tract as a supermarket did not extend to whites; in this population only a slight increase in meeting dietary fruit and vegetable requirements was associated with the presence of at least one supermarket. This finding suggests that social and cultural environmental factors, as well as the built environment, influence eating behaviors at the neighborhood level. The importance of social influences at the neighborhood level have been identified as critical when examining the increased risk associated with residence in a neighborhood with relatively high rates of obesity prevalence.[59]

In a companion study, Morland et al.[42] further analyzed the results of the ARIC study with respect to the association between retail food outlets (supermarkets, grocery stores, and convenience stores), obesity, and cardiovascular disease risk factors. In this study, they found the presence of one supermarket within an individual's census tract was associated with a 9% lower prevalence of overweight, 24% lower prevalence of obesity, and 12% lower prevalence of hypertension. Adjusting the model for socioeconomic and physical activity behaviors (leisure index, sports index, and work index) resulted in an attenuation of the influence of supermarkets on the prevalence of overweight, obesity, and hypertension. In contrast, residing in the same census tract as a convenience store was associated with an increased prevalence of overweight, obesity, and hypertension. The associations between overweight, obesity, hypertension, and the presence of convenience stores were slightly attenuated with the inclusion of sociodemographic and physical activity behavioral factors, but they remained significant after model adjustment. Of particular interest were the results obtained when looking at different combinations of access to supermarkets, grocery stores, and convenience stores and their associations with obesity. People living in areas with any combination of food stores, with the exception of only supermarkets and grocery stores, had a higher prevalence of overweight and obesity, as compared to those living in areas with only supermarkets. The greatest risk for an increase in obesity was associated with an absence of supermarkets in the census tract and the presence of one or more grocery and/or convenience stores. This finding is critical when juxtaposed against retail trends of supermarket consolidation and the location of supermarkets on the urban or suburban periphery.[60]

A recent study by Inagami[61] highlights the importance of examining not only localized neighborhood retail food environments, but also preferred grocery stores, when assessing the impact of retail food environment exposures. The study used individual-level data from the Los Angeles Family and Neighborhood Study survey that included self-reported weight and height measures (used to calculate BMI), as well as information about income, transportation (car ownership), and the location of the grocery store relied upon for grocery shopping.

Along with the expected findings that variability in BMI was associated with age, race/ethnicity, and education, multilevel analysis indicated a gradient between BMI and area-level SES measures that persisted among all neighborhoods, with a 1.51 unit increase in BMI between those residing in the lowest and highest SES neighborhoods. Car ownership was also independently associated with an increase in BMI of approximately 0.762 units. Choice of grocery store and distance to grocery stores were independent predictors of BMI, with shopping at grocery stores located within a higher SES area (along the SES gradient) associated with lower BMI and distances $\geq$1.76 miles predictive of a 0.775 unit increase in BMI. Significant interactions between residential SES and aggregate differences in SES between residence and grocery store location existed, with BMI significantly higher when individuals in lower SES areas lived in areas where the average individual frequented local (low SES) grocery stores, as compared to individuals who lived in and shopped in the highest SES areas.

The results highlighting the importance of shopping behavior offer important insight into the difficulties of utilizing local retail food environment as a single exposure variable. Instead, these results suggest that, at least within an urban context, the ability to shop in grocery stores in neighboring, more affluent neighborhoods potentially mitigates the impact of residing in a disadvantaged neighborhood.

As with other multilevel studies reviewed, the determination of causality is limited by the lack of temporal information, and reliance on food store type (while mediated by the integration of store location by area-level SES) as an indirect measure may have resulted in some misclassification of food environments. Lastly, as in all the studies reviewed here, life-course SES exposures (which would be assumed to be associated with life-course food and nutrition environment exposure), which have been suggested as a significant factor in the development of obesity, are not taken into consideration.[11, 62, 63]

Conclusion

Based on this review of the literature, we would like to suggest an omnibus hypothesis associated with the relationship between neighborhood retail food environments, SES and food choices associated with obesity. Specifically, as suggested by Figure 1, we hypothesize that while the quality of the retail food environment affects food choice and eating behaviors among both high and low SES populations, the economic (and perhaps social and cultural) resources available to those of higher SES have a protective effect on eating patterns. This effect is consistent with a cross-level confounding effect as described by Blakely and Woodward[64] in which an individual-level variable (SES) acts as a confounder on the ecological (food environment) variable. This hypothesis builds upon previous research suggesting that low SES and food pricing patterns discourage healthy eating on an individual level,[41, 65, 66] but it also incorporates critical neighborhood-level factors that contribute to unhealthy eating patterns and risk of obesity. Recognizing and measuring the multilevel influences of the retail food environment on eating behaviors (and risk of obesity) is a critical prerequisite for the development of multilevel interventions that address barriers and facilitators at both the individual and environmental level.

This hypothesis also explicitly acknowledges that while the presence of a high-quality food environment is a necessary condition for the adoption of healthy eating behaviors, it is not sufficient for ensuring healthy eating behaviors. One of the criticisms of much of the research on the relationship between food access and obesity is that it assumes a relatively simplistic deprivation effect associated with poor-quality food environments[34, 67]. The cross-level moderating effect proposed within this hypothesis recognizes that the health outcome of interest (healthy eating) is moderated by other environmental factors (such as transportation, social capital and culture) in addition to being mediated by individual-level characteristics, including food price.

The relationship between food environments and obesity is extremely complex, and it is unlikely that any single study will yield a complete and accurate picture of how changes in our local food environments have contributed to the obesity epidemic in the United States However, this review does highlight some critical gaps in our knowledge base that can potentially be addressed in future studies. One of the most critical research needs is for longitudinal studies that permit temporal associations to be determined between food and nutrition exposure and obesity. A recently released short paper highlights the potential for using reliable and valid historical data on grocery store location, and future studies should explore these data sources.[68] Longitudinal data associated with life-course exposure to food and nutrition environments would also be of great utility in understanding the cumulative effect of food environment exposures on eating behaviors and obesity.[63]

Another critical need is for studies that investigate food and nutrition environments in non-urban settings. Approximately 20% of Americans live in areas that can be classified as rural, and the prevalence of obesity is generally higher in rural as compared to urban areas.[24, 69] Results from the Inagami[61] study showing driving distance as an independent predictor of BMI suggest that the significant distances rural residents drive to purchase foods may contribute to unhealthy eating patterns in these areas. Additionally, rural areas provide an opportunity to study the mechanisms underlying the relationship between food environments and eating patterns in the absence of significant socioeconomic and racial segregation in housing patterns.

Lastly, given the multiplicity of factors associated with weight gain at an individual level, studies are needed that involve direct observation of environmental correlates of physical activity, other health behaviors, and area-level socioeconomic correlates (particularly food insecurity).[8, 70] Multilevel, mixed methods studies offer the potential to provide a more complete picture of the direct and perceived environmental influences on healthy behaviors.[71]

Understanding the role of food access and availability on food and nutrition environments, and ultimately on obesity, offers significant potential for the development of evidence-based interventions and policies to combat the growing epidemic of obesity in the United States and throughout the world. While a daunting task, a better understanding of these complex environmental interactions and impacts on obesity is a critical prerequisite for addressing the even more daunting health issues associated with obesity.

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Figures and Tables

Figure 1-1 Protective effect of socioeconomic status (SES) on moderating the impact of poor-quality food environment on eating behaviors linked to obesity

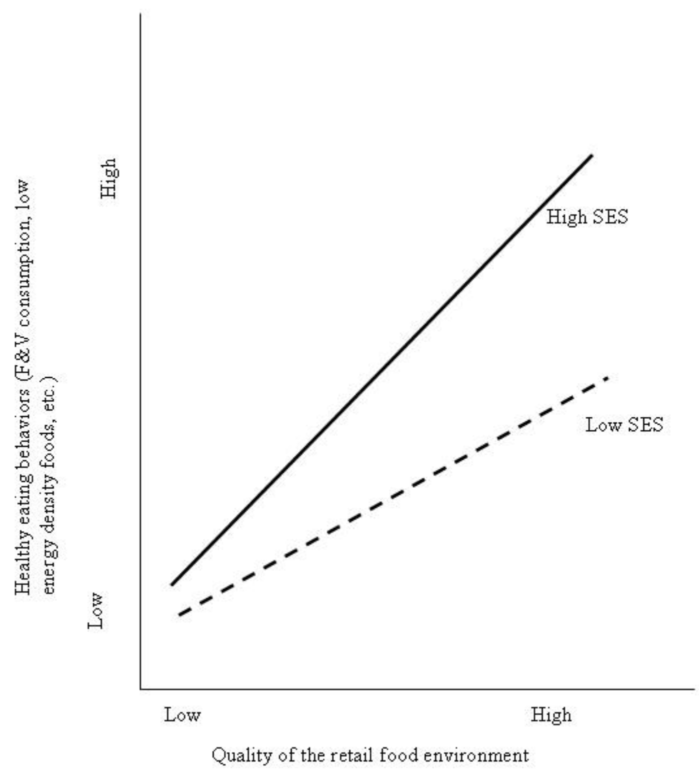

Table 1-1 Summary of studies related to hypothesis 1—geographic differences in the access and availability of foods result in disparities in the retail food environment

Reference	Location/setting	Food environment measure/method	Key findings
Morris et al (1992)[72]	National (direct observation in rural areas)	Store type	a) Average food costs 20% higher in small/medium grocery stores as compared to supermarkets.
		Market basket	b) Fruit and vegetable availability limited in small/medium grocery stores. c) 32% of residents in persistently poor rural counties redeemed food stamps at small/medium grocery stores as compared to 20% redemption rates in small/medium grocery stores.
Chung et al. (1993)[44]	Minneapolis, MN (urban)	Store type	a) Chain stores prices significantly lower with greater variety of foods available as compared to convenience and small grocery stores.
		Market basket	b) Chain stores less prevalent in urban core areas. c) Gap between urban core and suburban TFP basket significant and due primarily to presence of chain stores (chain stores $16 price reduction) with net impact of poverty to increase price of basket by approximately 3%.
Horowitz et al. (2004)[49]	New York City – Paired comparison - East Harlem (low SES, high ethnic	Market basket	a) 18% of grocery stores in low SES neighborhoods stocked foods associated with recommended diet, as compared to 58% of grocery stores in high SES neighborhoods.

	minority pop.) and - Upper East Side (high SES and low ethnic minority pop.)		b) Only 9% of low SES bodegas carried recommended foods as compared to 48% of high SES bodegas.
Block et al. (2006)[43]	Chicago – Paired comparison 1. Austin (low SES, high ethnic minority pop.) 2. Oak Park (high SES and low ethnic minority pop.	Market basket, including quality characteristics (participatory, direct observation)	a) Affluent neighborhoods had more chain grocery stores and supermarkets, while less affluent neighborhoods had more "low-cost" retail grocery chains. b) Price differentials between neighborhoods not significant when controlling for store type. c) Produce in Austin neighborhood rated as lower quality as compared to produce in Oak Park.

Table 1-2 Summary of studies related to hypothesis 2—neighborhoods of low socioeconomic status with high concentrations of racial/ethnic minorities have limited accessibility and availability of healthy foods (poor-quality retail food environment)

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
Horowitz et al. (2004)[49]	New York City – East Harlem (low SES, high ethnic minority pop.) and Upper East Side (high SES and low ethnic minority pop.)	Ecological design, direct observation of food environment measures	Store type Price and availability of core foods needed for diabetic diet	Neighborhood-level variables – income, race/ethnicity	a) 18% of grocery stores in East Harlem stocked foods associated with recommended diet, as compared to 58% of grocery stores in the Upper East Side b) Only 9% of East Harlem bodegas carried recommended foods as compared to 48% of Upper East Side bodegas
Zenk et al. (2005)[25] and Zenk et al. (2006)[52]	Detroit, MI	Cross-sectional design, Chi-square and spatial regression, Geographic Information Systems(GIS)	a) Store type	Individual-level variables – income, race/ethnicity	a) Quality of fresh produce lower in predominantly African American low SES (AA-low SES) communities as compared to racially heterogeneous middle income communities (RH-mid SES), even after adjusting for store type b) 97% of AA-low SES live within 1 mile > 8 liquor stores, as compared to 87.9% in RH-low SES, 59.3% AA-mid SES and 0% RH-mid-SES

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
			b) Distance to supermarket		c) Selection (#) and price of produce did not vary significantly by store type or neighborhood
				Neighborhood-level SES. Race-average income and racial composition	d) Within lowest SES group, African American neighborhoods have 2.7 fewer supermarkets within 3-mile radius as compared to white neighborhoods
			c) Price and availability of fruits and vegetables		e) Within lowest SES group, African Americans resided 1.1 miles further from supermarket as compared to white residents f) Interaction between race/ethnicity significant and inclusion of interaction term improved spatial regression model fit (ι^2=15.83, p<0)
Moore et al. (2006)[48]	North Carolina (n=75 census tracts)	Cross-sectional design, Poisson regression, and multilevel analysis	Store type	Individual-level variables – income and race/ethnicity	a) Minority and racially mixed neighborhoods, after adjusting for population ratio, had more grocery stores and fewer supermarkets than white neighborhoods (African American tracts SR=0.5; 95% CI 0.3–0.7; mixed tracts SR=0.7, 95% CI 0.5–0.9)

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
	Maryland (*n*=276 census tracts)			Neighborhood variables – average income and racial composition	b) Lower income neighborhoods had half as many supermarkets as compared to affluent neighborhoods (SR=0.5; 95% CI 0.3–0.8)
	New York (*n*=334 census tracts)			Model adjusted for confounders, including population density	
Baker et al. (2006)[47]	St. Louis, MO (n=220 census tracts)	Ecological design, direct observation of food environments, spatial clustering statistics	a) Supermarket audit tool and creation of z score	a) Neighborhood variables – % below poverty level and race/ethnicity at census tract	a) Spatial clustering of supermarkets (unadjusted and without including quality ranking) was not significant ($p<0.50$); however, clustering by race/ethnicity was observed b) Spatial clustering of supermarkets using quality scores (z score from audit) was significant ($p<0.01$; $p<0.03$) with supermarkets in highest two quality tertiles clustered in census tracts with >75% white and <10% below poverty

Reference	Location/setting	Research design, methods, and analysis	Outcome variable	Explanatory variables	Key findings
Powell et al. (2006)[40]	National	Ecological design, multivariate analysis	a) Store type	a)Neighborhood variables – income, race/ethnicity,	a) Low-income neighborhoods had 25% fewer supermarkets as compared to middle-income neighborhoods (*p*<0.01)
				b) Regional/other confounders – population density, region, degree of urbanization	b) After controlling for income and other covariates, the availability of supermarkets in African-American neighborhoods was only 48% of white neighborhoods (*p*<0.01). c) Hispanic neighborhoods have 32% as many supermarkets as compared to non-Hispanic neighborhoods (*p*<0.01)
Morland et al. (2007)[53]	Brooklyn, NY	Cross-sectional design, direct observation, Poisson regression	a) Store type	a) Neighborhood racial segregation	a) Prevalence of supermarket varied by neighborhood composition, with white, racially mixed, and black areas having 0.33, 0.27, and 0.0 supermarkets per census tract, respectively
			b) Availability fresh, canned, frozen and prepared produce	b) Neighborhood confounders – population density and neighborhood wealth (median house value)	b) 64% of fresh produce surveyed had a higher presence in predominantly white areas, as compared to 31% in racially mixed and 5% in predominantly black areas

Table 1-3 Summary of studies related to hypothesis 3—individuals exposed to poor-quality retail food environments are more likely to have diets that include foods of low nutritional quality and high caloric density, and higher rates of obesity, as compared to individuals exposed to high-quality food environments.

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
Morland et al. (2002)[58]	North Carolina, Maryland, New York (*n*=10,623)	Cross-sectional design, multilevel analysis, Geographic Information Systems (GIS)	Fruit and vegetable intake	a) Individual-level variables – income, educational attainment, region, race/ethnicity	a)After adjusting for income and education, five times as many supermarkets were available in neighborhoods with >75% white population; only 8% of African Americans lived in census tract with supermarket (p<0.01) b) African Americans living in the same census tract as a supermarket were more likely to meet the dietary guidelines for fruit and vegetable consumption (RR=1.32; 95% CI 1.40–1.80). This effect did not extend to whites (RR=1.11; 95% CI 0.93–1.32)

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
				b) Neighborhood variables – store type, SES, race/ethnicity	c) Relationship between residence in same tract as supermarket exhibited dose-response effect, with a 32% increase in fruit and vegetable consumption among African Americans corresponding for each additional supermarket (RR=1.32; 95% CI=1.08–1.60)
Morland et al. (2006)[42]	North Carolina, Maryland, New York (*n*=10,623)	Cross-sectional design, multilevel analysis, Geographic Information Systems	a) Body mass index	a) Individual-level variables – income, race/ethnicity	a) Presence of a supermarket within a census tract was associated with a 9% lower prevalence rate of overweight (PR=0.91; 95% CI 0.87–0.95) and a 22% lower prevalence rate of obesity (PR= 78; 95% CI 0.67–0.85) and a 12% lower prevalence of hypertension (PR=88%; 95% CI 0.79–0.97)
			b) Hypertension	b) Neighborhood-level variables – store type, race/ethnicity, income	b) Adjustment for socioeconomic and physical activity behaviors resulted in an attenuation of effect for overweight (PR=0.94; 95% CI 0.90–0.98), and obesity (PR=0.88; 95% CI 0.75–0.95)

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
			c) Other CVD risk factors		c) Presence of convenience store within a census tract was associated with increased prevalence of overweight (PR=1.07; 95% CI .02–1.12); obesity (PR=1.19; 95% CI 1.05–1.25), and hypertension (PR=1.12; 95% CI=1.01–1.25) d) Greatest prevalence of overweight and obesity found in communities with combination of no supermarkets and one or more grocery stores and/or convenience stores
Inagami et al. (2006)[61]	Los Angeles, CA (*n*=2620)	Cross-sectional design, multilevel analysis	a) Body mass index	a) Individual-level variables – distance to shops, shop disadvantage score, car ownership, shopping patterns (within/outside of census district) Controlled for gender, age, education, race/ethnicity, employment,	a) 13% of African Americans and 15% of Asians shop within their own census tract, as compared to 23% of whites. b) Owning a car associated with additional 0.762 BMI units, Latino ethnicity associated with additional 1.5 BMI units, and African American ethnicity associated with 2.4 BI units (*p*<0.01)

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
				marital status, income	c) College education associated with 1.32 reduction in BMI (*p*<0.01). d) Family income, marital status and gender not associated with differences in BMI.
				b) Neighborhood variables – Neighborhood-level disadvantage (%< poverty + % female households + male unemployment + % public assistance)	e) Gradient effect associated with living in a very low SES area with 1.51 unit increase in BMI, as compared to a 1.17 unit increase in BMI for lower-middle SES, and 0.893 unit BMI increase for highest BMI f) When model includes grocery store disadvantage, living in very low SES neighborhood results in 2.11 unit increase in BMI (*p*<0.0001)

Reference	Location setting	Research design and method of analysis	Outcome variable	Explanatory and confounding variables	Key findings
					g) Shopping distance ≥1.76 miles independently associated with 0.775 unit increase in BMI (*p*<0.01)

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CHAPTER 2 - Geographic, racial, ethnic, and socioeconomic disparities in the spatial availability of grocery stores and supermarkets among low-income women across the urban-rural continuum

Introduction

Within industrialized countries, access to grocery stores and supermarkets that carry healthy food items is a necessary, but not sufficient, condition for maintaining a healthy diet. A growing body of research suggests that there are significant geographic, racial, ethnic, and socioeconomic disparities in the availability of supermarkets and grocery stores [1-7], and that these structural disparities contribute to disparities in the prevalence of obesity among disadvantaged groups [8-12]. Attention to the availability of supermarkets and grocery stores, and concern over the local food environment, is central to the socioecological approaches to health behaviors in which neighborhood environmental features (like grocery stores and supermarkets) are hypothesized to facilitate eating behaviors associated with appropriate weight maintenance and good health [13].

To date, most of the studies examining supermarket availability in the U.S. have found a relatively consistent relationship between area deprivation, high percentages of racial/ethnic minorities, and reduced availability of supermarkets [1, 14]. For instance, in a study of supermarket availability within the Detroit, MI metropolitan area, Zenk [15] found that the nearest supermarket was 1.1 miles further in predominantly (> 60%) African American census tracts, as compared to low minority tracts. Similarly, Morland [7] identified 5 times more supermarkets in low minority tracts as compared to high minority tracts in Maryland, North Carolina, Mississippi, and Minnesota. In a national study of supermarket and grocery store availability, Powell [16] observed that low-income ZIP codes had only 75% as many chain supermarkets as middle-income zip codes, and the availability of chain supermarkets in high minority ZIP code areas was less than half of that observed in low minority ZIP codes. Disparities in the availability of grocery stores and supermarkets by rurality have also been noted, as in a study in rural South Carolina in which 40% of very rural tracts had a supermarket as compared to 67% of the more urbanized tracts [6]. In a study within 36 rural, high poverty counties in the Mississippi Delta Region, Kaufman [17] reported that over 70% of households eligible to receive food stamps had to travel in excess of 30 miles to reach a large grocery store or supermarket.

However, several recent studies suggest that these associations are neither as clear nor as universal as previously presumed. In one of the few detailed studies on food environments in rural areas, Sharkey and Horel [18] calculated network distances from population-weighted center of census block groups within a 6-county rural region, and determined that the most deprived neighborhoods with the highest percentage of minority residents had better potential spatial access to both supermarkets and grocery stores, as compared to more affluent and less racially diverse census block groups. Similarly, reports from the United Kingdom [19, 20], Canada [21, 22], New Zealand [23], and Australia [24, 25] suggest relatively widespread availability of grocery stores and healthy foods for urban residents in socioeconomically disadvantaged communities.

One reason for the inconsistency in results may be associated with Modifiable Areal Unit problems (MAUP), which arise when artificial units of categorization (like census tracts) are imposed on continuous geographic phenomenon. The result is the generation of erroneous relationships among spatial variables [26, 27]. Most studies within the U.S. examining disparities in supermarket availability have examined relationships among food environment and health behaviors at the ecological level using census tracts or ZIP codes as the administrative unit of analysis [28]. Implicit in this study design is the assumption that census tracts are appropriate units for examining store availability and grocery shopping behaviors. However, several recent studies suggest that the most grocery shopping is not constrained by census tracts and the location of stores nearby (but not within the same census tract) may be an important influence on health behavior. In a study in metropolitan Los Angeles, Inagami [29] reported that only 23% of whites and Hispanics, 13% of Asians, and 15% of blacks conducted most of their grocery shopping within their own census tract [30]. Qualitative studies investigating grocery shopping behaviors consistently report that cost, selection, and convenience of location (including proximity to work) are the primary factors influencing their decision about where to shop

[31-33]. Additionally, because census tracts are very large in geographic extent in less populated areas, they may be even less appropriate for examining the local food environment in very rural areas [34].

This study was undertaken to examine whether MAUP issues bias estimates of store availability, and to examine store availability across the urban-rural continuum by determining the availability of small grocery stores and supermarkets at an individual level for women participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). The first hypothesis tested in this study is that store availability estimates and the associations between store availability and individual demographic characteristics observed within a 1-mile radius of WIC residence would parallel those obtained when examining availability and associations at the census tract level. We further hypothesized that WIC participants that lived in rural areas, who were black or Hispanic, and had low educational and income levels would have fewer supermarkets and small grocery stores, as compared to WIC participants who were white, non-Hispanic, and had higher income and educational status.

Methods

Study population - Women, Infants, and Children (WIC) mothers

The observational dataset used for this study included all Kansas women enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) between October 10, 2004 and December 31, 2006. To be eligible for the WIC program a participant must be a pregnant, breastfeeding, or postpartum mother with children under 5 years of age, and have a household income < 185% of the federally designated poverty level. Certification in the WIC program is automatic for women and children enrolled in the Supplemental Nutrition Assistance Program (SNAP), Temporary Assistance to Needy Families (TANF), and Medicaid programs. However, unlike these federal assistance programs, participation in the WIC program does not require any certification of citizenship. The initial study population included 25,032 unique cases. Cases were excluded if the street address was missing or incomplete. The final sample eligible for geocoding was 23,351. The street address was used to geocode each WIC mother's home residence within ArcGIS (Redlands, CA). The final geocoded sample was 21,203

(90.8%). Cases were excluded if the mother was < 18 or > 50 years of age at the time of certification, and if post-partum BMI was recorded as < 15 or missing. There were no significant differences in WIC characteristics by geocoding status. The final sample included 21,166 unique cases. Selected characteristics of WIC mothers are presented in Table 2-1.

Study Setting - Kansas

The estimated population of Kansas in the 2000 Census was 2,688,418, residing within a land area of 81,815 square miles. Kansas has a relatively low population density, with an average of 32.9 persons per mile^2, as compared to a 79.6 persons per mile^2 average for the U.S. (US Census Bureau, 2000 Census). To differentiate between counties across the urban-rural continuum, county designations based on urban influence were obtained from the USDA-ERS Urban Influence Codes, which classifies counties based on population density, presence of population centers, and adjacency to a metropolitan area (USDA-ERS, 1983). The twelve urban Urban Influence Codes (2 metropolitan UIC;s and 10 non-metropolitan UIC's) were collapsed into three categories: metropolitan (UIC 1,2), micropolitan (UIC 3, 5, 8) and rural (UIC (4,6,7,9,10,11,12) based on groupings previously identified as relevant to employment and economic patterns in Kansas [35]. Rural counties in Kansas (n=69) contain approximately 68% of the land area of Kansas, but only 16% of the 2000 Kansas population, with an average population density of 76 persons per square mile. In contrast, metropolitan counties (n=17) contain approximately 13% of the land area, 61% of the 2000 population, and have an average population density of 2,407 persons per mile^2. Micropolitan counties (n=19) included population centers between 10,000-50,000 residents, contain 19% of the land areas, 22% of the 2000 Kansas population, and have an average population density of 1,081 persons/mile^2.

A total of 727 census tracts were identified in the 2000 Census of Kansas, of which 7 tracts had fewer than 100 residents and were excluded from the analysis. Of the 720 census tracts, 422 were in metropolitan counties, 148 were in micropolitan counties, and 150 were in rural counties. Tract sizes varied widely along with urban-rural continuum, with a mean metropolitan tract size of 26.22 miles^2 (SD=74.54 miles^2), mean micropolitan tract size of 103.65 $miles^2$ (SD=181.89 $miles^2$), and mean rural tract size of 369.30 $miles^2$ (SD=318.64).

Grocery Store and Supermarket Enumeration and Availability

A complete listing of food stores was obtained from the Kansas Department of Agriculture retail food licensure list for 2005. Under Kansas law, all stores selling food items are required to be licensed and inspected in compliance with Kansas Food Code (Kansas Department of Agriculture Food Code, 2005). Store license records included store type based on self-identification in eight categories: bakery, bakery outlet, convenience store, fruit/vegetable market, grocery store, health food store, retail meat store, specialty shop, and variety shop. Stores were also classified by size: < 5,000 ft^2, 5,000 -15,000 ft^2, and > 15,000 ft^2. The final geocoded stores were re-coded into five categories based on store type and size. The final categories included: 1) convenience stores; 2) small grocery stores (< 15,000 ft^2); 3) supermarkets (grocery stores > 15,000 ft^2); 4) specialty stores (bakery, bakery outlets, fruit/vegetable markets, health food stores, retail meat stores, and specialty stores); and 5) variety stores. Stores in the variety category included general merchandise stores (e.g., dollar stores, pharmacies, and general merchandise stores without a specific grocery section). Super centers with substantial grocery sections (e.g., Wal-Mart Super centers, Target Super Centers) were coded as supermarkets.

The full listing of retail food stores licensed in 2005 (n=2,680) was geocoded by street address within ArcGIS (v. 9.2, Redlands, CA). A total of 2,520 (94.90%) stores were successfully geocoded to the street address level. The majority (73%) of stores that were not geocoded were convenience stores. The number of stores by store type and urban influence category are presented in Table 2-2.

Euclidean buffers of 1-, 3-, and 5-mile radius were drawn around each WIC residence within ArcGIS using the Spatial Analyst Tool in the North American Datum (NAD) 1983 UTM Zone 14N Projection System. Hawth's Analysis Tool for ArcGIS Tools Point in Polygon function (http://www.spatial ecology.com/index.php) was used to enumerate store types within census tract, and within each radius around individual WIC mother's residences.

Statistical analysis

All data were reduced and analyzed using SPSS software (v. 15.0, SPSS Inc., Chicago, IL). Differences between store availability within census tracts and at each radius around WIC home residence were assessed by descriptive statistics and one-way analysis of variance. Multivariate count (Poisson) regression models, stratified by urban influence category, were used to estimate incidence rate ratios for the availability of different types of retail food stores within census tracts, and within a 1-,3- , and 5-mile radius of WIC residence. Population density of census tract was controlled when estimating store availability by tract. In situations where count data were overdispersed, negative binomial models were run and contrasted with Poisson models using AIC criteria. In all cases, Poisson models had equal or improved model fit as compared to negative binomial models.

Results

Store Availability By Urban Influence

The number and percentages of store types, by store category and urban influence are presented in Table 3-2. Convenience stores represented almost half of the stores available within all urban influence categories, with micropolitan areas having a higher percentage of convenience stores, as compared to metropolitan and rural areas. Rural areas had the highest percentage of small grocery stores and supermarkets (27.04%) as a percentage of total stores, as compared to metropolitan (19.96%) and micropolitan (22.79%) areas. However, supermarkets constituted less than 4% of the stores available in rural areas as compared to 9.73% and 12.47% in micropolitan and metropolitan areas, respectively.

Table 2-3 includes the mean store availability, by urban influence category, of convenience, small grocery stores, and supermarkets within census tract and within a 1-, 3-, and 5-mile radius around the residence of each WIC mother in Kansas. Average store availability varied along the urban-rural continuum, with rural WIC mothers having consistently fewer stores available as contrasted to metropolitan and micropolitan WIC mothers. Rural WIC mothers had 52% and 75% fewer small grocery stores and supermarkets within a 1-mile radius of their residence as compared to micropolitan WIC mothers, and 41% and 74% fewer small grocery stores and supermarkets as compared to metropolitan WIC mothers. These results contrast with those obtained when examining disparities at the tract level, in which rural WIC mothers had greater availability of small grocery stores, as compared to both metropolitan and micropolitan WIC mothers. However, rural WIC mothers had 20% fewer supermarkets available in their census tract as compared to metropolitan WIC, and 42% fewer supermarkets as compared to micropolitan WIC mothers. Disparities in the spatial availability of supermarkets grew more significant at larger distances from WIC residence, with 10.83 supermarkets available in a 5-mile radius for metropolitan WIC cases, as compared to 3.23 supermarkets in micropolitan areas, and 0.41 supermarkets in rural areas.

Univariate Analysis by Sociodemographic Characteristics

Univariate results examining mean store availability by the demographic characteristics of WIC mothers, and stratified by urban influence category, are presented in Table 2-4. Within metropolitan areas, black WIC mothers had significantly fewer convenience stores and supermarkets within a 1-mile radius of their residence. However, as distance increased, black WIC mothers had greater availability of all types of stores. Store availability within census tracts also reveals significant disparities with black WIC mothers having significantly fewer convenience stores, small grocery stores, and supermarkets as compared to non-black WIC mothers.

Hispanic WIC mothers in metropolitan areas had greater availability of all types of stores at each radius from residence. These results are largely consistent with those obtained when examining store availability at the tract level; however, supermarket availability was not significantly different by ethnicity at the tract level.

Low educational status (< 12 years of education) was consistently associated with higher availability of all types of stores at each radius; however, when examining availability at the tract level, low educational status was associated with increased availability of small grocery stores and reduced availability of supermarkets, as compared to higher educational status. Annual income was not consistently associated with differences in the availability of stores assessed within a radius of WIC residence or by census tract, but there was a pattern observed in which the intermediate income category

($10,000-$15,000) was associated with greater availability of all types of stores, as compared to the lowest (< $10,000) and the highest income categories (> $15,000). It is important to be cautious in any interpretation of the information on income, however, because all of the WIC mothers in the study had incomes < 185% of the federally designated poverty level for family size.

Within micropolitan areas, black WIC mothers had significantly fewer convenience stores and small grocery stores within a 1- and 3-mile radius of residence as compared to white WIC mothers. There were no significant differences in supermarket availability at any distance from residence by race. However, when examining store availability within tracts, black WIC mothers had significantly fewer convenience, small grocery, and supermarkets available as compared to non-black WIC mothers. Hispanic ethnicity was associated with significantly more stores of every type at every radius and within census tract, as compared to non-Hispanic WIC mothers. These differences were greatest for grocery stores, with Hispanic WIC mothers having approximately twice as many small grocery stores within a 1-, 3-, and 5-mile radius, as compared to non-Hispanic WIC mothers. Low educational levels were also consistently associated with greater small grocery store access at most distances from WIC residence, and when examining store availability within census tracts. Income was not consistently associated with differences in the availability of stores at any distance from residence within the micropolitan WIC sample. However, when examining differences across census tracts, the intermediate income category was associated with increased availability of convenience stores and supermarkets, as compared to the lowest and highest income categories.

Within rural counties, store availability within census tracts was much higher than that assessed using radial distance from WIC residence, reflecting the large size of tracts within rural areas. Hispanic ethnicity was the only WIC characteristic consistently associated with differences in store availability. Within a 1-mile radius of residence, Hispanic WIC mothers had almost twice as many small grocery stores (0.94 stores) as compared to non-Hispanic WIC mothers (0.57 stores). Differences by ethnicity in the availability of supermarkets were less pronounced, but Hispanic WIC mothers had greater availability of supermarkets within a 1-mile radius of their residence as compared to non-Hispanic WIC mothers. Education and income were not consistently associated with differences in store availability in the univariate analysis within the rural sample.

Multivariate Analysis

Multivariate regression estimates of incidence rate ratios are presented in Table 2-5. Multivariate Poisson regression estimates are appropriate for count data, and the resulting parameter estimates can be interpreted as incidence rate ratios [36]. Within the metropolitan sample, when controlling for education and income, black WIC mothers had equal or greater availability of both grocery stores and supermarkets at all radial distances from their residence. Increases in the availability of supermarkets grew with distance from residence, with equal numbers available within a 1- mile radius, 20% more stores within a 3 mile radius, and 23% more stores within a 5-mile radius. Differences in the availability of small grocery stores were also evident, with black WIC mothers having 53% more small grocery stores as compared to non-black WIC cases within a 1-mile radius, and 67% and 61% more small grocery stores within a 3- and 5-mile radius. These results contrast with those obtained when examining store availability within census tracts in which black racial status was associated with 13% fewer supermarkets and 7% fewer small grocery stores availabile within their census tract, independent of income and education.

Hispanic ethnicity, controlling for income and education, was also associated with greater availability of both small grocery stores and supermarkets within their census tract and at every radius, with 93% more small grocery stores and 44% more supermarkets within a 1-mile radius as compared to non-Hispanic WIC mothers. Differences in the availability of small grocery stores and supermarkets, independent of income and educational status, were also apparent when examining store availability at the tract level, with Hispanic WIC mothers having 28% and 10% more small grocery stores and supermarkets in their residence census tract. Metropolitan WIC mothers with the lowest category of education (< 12 years) also had equal or increased availability of grocery stores and supermarkets, with the effect growing more pronounced as radial distances increased. Within a 1-mile radius, WIC mothers in the highest educational category (> 12 years of education) had 18% fewer small grocery stores, as compared to

WIC mothers with 12 years of education. There were no significant differences between the lowest and intermediate level of education at the tract level, but women with more than a high school education had 12% fewer small grocery stores and 8% more supermarkets as compared to WIC mothers with only 12 years of education. The effect of income was less consistent, but the lowest income categories were generally associated with equal or increased availability of small grocery stores and supermarkets, as compared to WIC mothers with annual incomes > $15,000. The availability of convenience stores was equal or greater among black, Hispanic, low educational status, and the lowest income group when examining availability using either a spatial metric or administrative unit within metropolitan areas.

Similar trends were apparent in the micropolitan sample, with equal or increased availability of all types of stores associated with black and Hispanic ethnicity among WIC mothers when examining store availability around WIC residence. The differences in availability were most pronounced for small grocery stores, with black WIC mothers having 15% more small grocery stores, and Hispanic WIC mothers having more than 2 times the number of small grocery stores within a 3-mile radius of their residence. Black racial status was not associated with any difference in the availability of supermarkets at any distance from residence in the micropolitan sample. However, when we examine disparities across census tracts, black racial status was associated with 34% fewer small grocery stores and 17% fewer supermarkets. Hispanic ethnicity was associated with greater availability of supermarkets, with 45% more supermarkets within a 1-mile radius. The association of Hispanic ethnicity with store availability at the tract level was slightly attenuated, but Hispanic ethnicity was still significantly associated with increased availability of small grocery stores and supermarkets, when controlling for education and income level. As in the metropolitan sample, the lowest education and income categories were generally associated with equal or increased availability of small grocery stores and supermarkets.

Within the rural sample, multivariate results show that Hispanic ethnicity was associated with significantly greater availability of convenience and small grocery stores at every radial distance, and at the tract level. Hispanic ethnicity was also associated with a 34% increase in the availability of supermarkets within a 1-mile radius, and a 31%

increase in availability of supermarkets at the tract level. There was no association between Hispanic ethnicity and supermarket availability at greater distances from residence. Very low income was associated with greater availability of convenience stores at every distance, and equal availability of small grocery stores and supermarkets as compared to WIC mothers with > $15,000 annual income. WIC mothers with less than 12 years of education had 5% fewer supermarkets within a 1-mile radius, and WIC mothers with > 12 years of education had 12% fewer small grocery stores within a 1-mile radius and 13% fewer small grocery stores within a 5-mile radius, as compared to WIC mothers with a high school education.

Discussion

The first hypothesis tested in this study is that associations between WIC mother's demographic characteristics and the availability of small grocery stores and supermarkets observed within a 1-mile radius of residence would parallel those observed when examining store availability within their census tract. Contrary to our original hypothesis, we discovered estimates and observed associations differed substantially between those obtained at the tract level versus those obtained when we examined store availability within a 1-mile radius of residence. For example, when examining store availability within metropolitan areas, mean small grocery store and supermarket availability within a 1-mile radius of residence was 2 times greater than estimated at the tract level. A similar pattern emerged when examining store availability among micropolitan WIC mothers, with 37% more small grocery stores and 38% more supermarkets within a 1-mile radius as contrasted to mean store availability at the tract level. As expected due to the very large tract size in rural areas, these patterns were reversed with mean availability greater at the tract level, as compared to availability measured within a 1-mile radius of WIC residence.

Results from our multivariate regression analyses also indicate that associational patterns observed at the tract level differ from those observed within a 1-mile radius of residence. Within metropolitan and micropolitan areas, black racial status was associated with a 13% and 17% reduction in supermarket availability at the tract level, representing a significant disparity in the availability of supermarkets. In contrast, there were no significant differences when examining supermarket availability associated with black status when store availability was measured within a 1-mile radius of residence. Similarly, within micropolitan areas, black status was associated with a 34% reduction in the availability of small grocery store at the tract level, but was not associated with significant differences when examining store availability within a 1-mile radius of residence.

It is worthwhile to examine some of the reasons why results obtained when examining small grocery store and supermarket availability within a 1-mile radius of individual WIC mothers differ from those obtained when examining racial/ethnic disparities at a tract level. Within Kansas high minority and low SES census tracts are substantially smaller than low minority/high SES census tracts, even within the same urban influence category. For instance, within metropolitan counties, high (> 40%) black tracts average 0.85 square miles, as compared to 2.17 and 31.19 miles^2 in intermediate (15-40%) and low (< 15%) black tracts. As a result of these differences in tract size, large disparities in the availability at a tract level do not necessarily translate to disparities when examining availability within a 1-mile radius because stores may be available in adjacent tracts. The results obtained in this study highlight the key role that MAUP issues may play in biasing estimates of disparities in the availability of small grocery stores and supermarkets, and suggest that future studies should explicitly address whether census tracts are an appropriate unit of analysis for examining food environments [26, 37, 38].

The second set of hypotheses tested the presence of geographic, racial and ethnic disparities in the availability of small grocery stores and supermarkets among WIC mothers in Kansas. In contrast to most previous research examining supermarket and small grocery store availability at the tract level, multivariate results from this research suggest that among low-income mothers participating in the WIC program in Kansas, racial and ethnic minorities, and those with very low incomes and educational levels actually have equal or greater availability of small grocery stores and supermarkets, as compared to white, non-Hispanic, and WIC mothers of greater income and educational status.

However, consistent with our original hypothesis, significant geographic disparities in the availability of small grocery stores and supermarkets are faced by WIC mothers who reside in rural areas, with rural WIC mothers having 59% of the grocery stores, and only 25% of the supermarkets within a 1-mile radius, as compared to metropolitan WIC cases. Interestingly, micropolitan WIC mothers had the greatest availability of both small grocery stores and supermarkets within a 1-mile radius of their residence, which is consistent with the hypothesis that concentration within the supermarket sector, combined with rural depopulation, have led to a loss of supermarkets in both urban and very rural areas [39.]

The results from our study have important implications for policy initiatives designed to increase the availability of healthy foods through supermarket development. Recent efforts to site supermarkets within high minority and low income urban neighborhoods are largely premised on evidence that these tracts contain significantly fewer supermarkets than less ethnically and racially diverse, and more affluent census tracts [40, 41]. However, if grocery shopping is not bounded by census tract, and if supermarkets are available in nearby census tracts, the potential dietary impact of these interventions may be limited. Results from interventions to increase availability of supermarkets in the U.K. suggest that dietary improvements associated with increased supermarket availability in deprived areas are either non-significant or minimal [42-46]. However, there may be important non-dietary benefits to supermarket interventions, including an enhancement of the perceptions of local food availability [47], improvements in the reputation of an area, and concomitant improvements in the psychological health of residents within an area [43].

Another important consideration associated with these initiatives is whether healthy food availability and pricing is better in large, chain supermarkets as compared to smaller, independent grocery stores. Results examining pricing and healthy food availability by store type indicate significant differences in availability and pricing between supermarkets and convenience stores[6, 48]; however, differences in the cost and availability between smaller grocery stores and chain supermarkets are less consistently reported [49-53]. For instance, within a rural environment in South Carolina, the availability of lean ground beef, skinless chicken, and frozen seafood was significantly greater in supermarkets, as compared to grocery stores, but differences in the average cost of items by store type were minimal and inconsistent [6]. In contrast, cost of food items associated with a Thrifty Food Plan market basket at small grocery stores within rural, upstate New York, did not differ significantly as compared to the same market basket at supermarkets, suggesting that grocery stores in rural areas may offer similar pricing for major food items [54]. Further research on food availability and pricing, particularly in rural areas where small grocery stores predominate, is needed to better understand how geographic disparities in store availability might contribute to higher prevalence of obesity in rural areas[55].

Most importantly, the results obtained in this study highlight the need for greater specificity in developing conceptual models examining the relationship between local food environments, grocery shopping, food choices, and diet. Specifically, most research on disparities in food environments suggest that a "spatial mismatch"[56] has arisen due to residential segregation, the flight of supermarkets from urban areas, and the loss of independent grocery stores from rural areas [54]. However, the results from this study suggest that disparities at the tract level do not necessarily correspond to spatial disparities in store availability, and that women in metropolitan and micropolitan areas have a multiplicity of supermarkets and grocery stores in which to shop within a relatively close distance of their residence. Future research should focus on identifying the factors that influence their choice of stores, and examine whether store choice influences dietary quality. Two particularly promising approaches include structural equation modeling [57] and dietary mapping [58], which can provide insight into the complex (and bi-directional) links between built, social, and cultural environments within localized areas.

Several limitations of this study must be noted. First, this study examined availability of stores among participants in the WIC program in Kansas, a sample which only included low-income women. Disparities in grocery store and supermarket availability would be expected to be more pronounced if we were examining store availability among individuals across a wider spectrum of socioeconomic status. Additionally, results from this study may not be transferable to other locations with different residential segregation and commercial patterns. A recent review of studies examining disparities in food store availability suggests that urban areas with high indices of segregation are likely to experience greater disparities in the availability of food stores[1]. This study also relied upon a statewide database of food stores from 2005. While the use of historical state data sources has been validated in other studies [59], recent ground-truthing studies suggest that non-differential misclassification of food stores may be an issue [6, 18]. There also may be significant differences in the quality and pricing of foods available at different stores, which are not considered in our statewide database.

Lastly, it is important to remember that spatial availability of grocery stores and supermarkets does not translate into functional accessibility and utilization of these stores. Utilization of stores that carry healthy foods is influenced by a multiplicity of factors, including pricing [60, 61], time constraints associated with shopping and food preparation [62], nutrition and cooking knowledge [63], and other social and cultural barriers that interact with structural barriers to healthy food purchasing [23, 57].

Despite these limitations, this study provides important information for understanding geographic, racial/ethnic, and socioeconomic disparities in the spatial availability of grocery stores and supermarkets. The first finding, that estimates of availability and associations observed at the census tract level are very different from those observed within a 1-mile radius of residence is noteworthy because it indicates that choice of the census tract as a unit of analysis may result in biased estimates and associations. The finding that there are significant geographic disparities in the availability of grocery stores and supermarkets in very rural areas of Kansas is also significant, particularly for women who lack access to a vehicle or social networks that would facilitate grocery shopping. However, in contrast to most other reports on disparities in the availability of grocery stores and supermarkets, the results indicating that racial/ethnic minorities and very low SES WIC mothers have equal or increased spatial availability of grocery stores and supermarkets within a reasonable distance of their residence is noteworthy. These results suggest that the spatial availability of healthy foods may play a less important role in determining dietary behaviors than previously hypothesized, and that future research should address the interaction of spatial availability, functional accessibility, and utilization of food stores within local environments.

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This research study received approval from the Kansas State University Institutional Research Board (IRB Approval #4035).

Tables

Table 2-1 Selected characteristics of WIC Mothers in Kansas (2004-2006).

	Full Sample (n=21,166)		Metropolitan (n=12,247)		Micropolitan (n=6,248)		Rural (n=2,671)	
	%	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD
Race/Ethnicity [1]								
White	84.99		78.40		92.38		97.87	
Black	11.83		17.29		5.60		1.35	
All other races[2]	4.21		5.67		2.62		1.27	
Hispanic	27.98		30.50		29.96		11.76	
Previous pregnancies		1.56 (1.73)		1.58 (1.77)		1.51 (1.57)		1.57 (1.87)
Age		24.80 (5.07)		24.94 (5.13)		24.67 (5.02)		24.42 (4.89)
Education (yrs)		11.46 (2.67)		11.42 (2.67)		11.46 (2.65)		11.61 (2.76)
Monthly Household Income ($)		1,328 (1,611)		1,300 (1,187)		1,375 (1187)		

[1] Race and ethnicity were included into one category; however, these items were asked separately on WIC intake forms. Total for race categories (white, black and all other categories) exceed 100% (100.9%) due to multiple races within an individual. Those classified as Hispanic could be designated as any race.
[2] Includes American Indian (n=427), Asian (n=416), and Pacific Islander (n=50) in the full sample. Sample sizes for these races/ethnicities were too small to allow for detailed analyses of other racial/ethnic categories.

Table 2-2 Number and percentage of stores by type and urban influence category

Store Type	Full Sample	Metropolitan	Micropolitan	Rural
Convenience Stores	1184	531	325	328
	(47.38%)	(43.85%)	(51.02%)	(50.38%)
Variety Stores	427	227	69	104
	(17.09%)	(18.74%)	(10.83%)	(15.98%)
Specialty Stores	289	177	96	43
	(11.56%)	(14.62%)	(15.07%)	(6.61%)
Small Grocery Stores	361	125	85	151
	(10.44%)	(10.32%)	(13.34%)	(23.20%)
Supermarkets	238	151	62	25
	(9.52%)	(12.47%)	(9.73%)	(3.84%)
Total Stores	2,499	1,211	637	651

Table 2-3 Mean number and types of retail food stores within a 1-, 3-, and 5-mile radius of WIC cases by urban influence category

Radius and Store Type	Metropolitan (n=12,263) Mean ± SD	Micropolitan (n=6,248) Mean ± SD	Rural (n=2,686) Mean ± SD
1 mile convenience stores	2.88a ± 1.93	3.63b ± 2.79	2.24c ± 6.18
1 mile small grocery stores	1.03a ± 1.43	1.26b ± 1.58	0.61c ± 0.79
1 mile supermarkets	0.84a ± 0.90	0.89b ± 0.99	0.22c ± 0.44
3 miles convenience stores	17.67a ± 8.77	11.35b ± 6.91	3.17c ± 6.37
3 miles small grocery stores	5.86a ± 5.16	3.09b ± 2.54	0.73c ± 0.84
3 miles supermarkets	5.07a ± 3.19	2.83b ± 2.00	0.39c ± 0.56
5 miles convenience stores	36.71a ± 17.99	13.65b ± 7.50	3.43c ± 6.36
5 mile small grocery stores	11.01a ± 7.70	3.44b ± 2.63	0.81c ± 0.88
5 mile supermarkets	10.83a ± 7.06	3.23b ± 2.04	0.41c ± 0.58
Tract convenience stores	1.50a ± 1.33	2.77b ± 2.07	2.80b ± 1.76
Tract small grocery stores	0.39a ± 0.67	0.91b ± 1.50	0.94c ± 0.89
Tract supermarkets	0.40a ± 0.64	0.55b ± 0.64	0.32c ± 0.52

Notes: Means within row followed by different letter are significantly different at $p < 0.05$ level using Games-Howell post-hoc procedures.

Table 2-4 Mean store availability within tract, 1-, 3-, and 5-mile radius of WIC cases, by race, ethnicity, education, and income, and stratified by urban influence category

Individual characteristic	(%)	Tract Conv. Mean (SD)	Tract Small Grocery Mean (SD)	Tract Super-market ean (SD)	1 mile Conv. Mean (SD)	1 mile Small Grocery Mean (SD)	1 mile Super-market Mean (SD)	3 mile Conv. Mean (SD)	3 mile Small Grocery Mean (SD)	3 mile Super-market Mean (SD)	5 mile Conv. Mean (SD)	5 mile Small Grocery Mean (SD)	5 mile Super-market Mean (SD)
Metropolitan Sample (n=12,263)													
Race													
Black	17.28	1.19a	0.34a	0.35a	2.78a	1.11a	0.76a	19.42a	7.07a	5.38a	40.62a	13.77a	11.02a
		(1.12)	(0.65)	(0.66)	(1.67)	(1.48)	(0.88)	(6.63)	(4.90)	(2.53)	(12.64)	(7.01)	(6.23)
Not Black	87.72	1.57b	0.40b	0.41b	2.90b	1.02b	0.86b	17.30b	5.61b	5.00b	35.89b	10.43b	10.67b
		(1.36)	(0.68)	(0.64)	(1.98)	(1.42)	(0.90)	(9.11)	(5.18)	(3.31)	(18.82)	(7.71)	(7.21)
Ethnicity													
Hispanic	30.47	1.41a	0.48a	0.41a	3.47a	1.56a	1.05a	21.07a	8.13a	5.98a	43.90a	13.91a	12.98a
		(1.25)	(0.71)	(0.64)	(2.00)	(1.64)	(0.92)	(6.64)	(5.24)	(2.99)	(13.38)	(6.72)	(6.46)
Not Hispanic	69.53	1.55b	0.36b	0.40a	2.62b	0.81b	0.74b	16.17b	4.86b	4.67b	33.56b	9.73b	9.89b
		(1.36)	(0.65)	(0.64)	(1.84)	(1.27)	(0.87)	(9.16)	(4.80)	(3.20)	(18.83)	(7.76)	(7.11)
Education													
< 12 yrs.	34.81	1.43a	0.44a	0.39a	3.19a	1.36a	0.89a	19.51a	7.26a	5.40a	40.45a	12.80a	11.75a
		(1.27)	(0.68)	(0.63)	(2.01)	(1.61)	(0.88)	(7.85)	(5.45)	(3.04)	(16.14)	(7.44)	(6.69)
12 yrs.	23.75	1.55b	0.39b	0.40ab	2.67b	0.94b	0.80b	16.83b	5.37b	4.84b	35.13b	10.38b	10.27b
		(1.35)	(0.64)	(0.63)	(1.93)	(1.36)	(0.90)	(8.96)	(4.94)	(3.22)	(18.66)	(7.70)	(7.07)
> 12 yrs.	41.44	1.54b	0.33c	0.43b	2.74b	0.72c	0.84b	16.43b	4.66c	4.97b	33.99c	9.47c	10.46b
		(1.36)	(0.67)	(0.68)	(1.82)	(1.15)	(0.91)	(9.26)	(4.63)	(3.33)	(18.48)	(7.57)	(7.45)
Annual Income													
< $10, 000	34.40	1.53a	0.40a	0.40a	2.77a	0.98a	0.80a	17.65a	5.67a	4.99a	36.38a	10.94a	10.64a
		(1.33)	(0.68)	(0.64)	(1.86)	(1.37)	(0.90)	(8.89)	(5.00)	(3.16)	(18.20)	(7.80)	(7.09)
$10,000-$15,000	17.04	1.47a	0.41a	0.39a	3.00b	1.13b	0.86b	18.67b	6.30b	5.38b	38.76b	11.71b	11.57b
		(1.31)	(0.68)	(0.65)	(1.89)	(1.46)	(0.88)	(8.27)	(5.17)	(3.19)	(16.97)	(7.48)	(6.94)
> $15,000	48.55	1.50a	0.39a	0.40a	2.91b	1.04a	0.86b	17.32a	5.84a	5.00a	36.22a	10.80a	10.70a
		(1.33)	(0.66)	(0.64)	(1.98)	(1.46)	(0.90)	(8.83)	(5.27)	(3.21)	(18.15)	(7.69)	(7.07)
Micropolitan Sample (n=6,254)													
Race													
Black	5.60	2.20a	0.43a	0.56a	3.50a	0.95a	0.81a	12.39a	2.79a	2.65a	15.59a	3.17a	3.16a
		(1.65)	(0.75)	(0.61)	(2.51)	(1.23)	(0.94)	(6.99)	(1.97)	(2.03)	(7.25)	(1.93)	(2.10)

Not Black	94.40	2.80b	0.93b	0.43b	3.64a	1.27b	0.89a	11.29b	3.11b	2.84a	13.53b	3.45b	3.23a
		(2.09)	(1.53)	(0.64)	(2.81)	(1.59)	(0.99)	(6.90)	(2.57)	(2.00)	(7.50)	(2.66)	(2.04)

Individual characteristic	(%)	Tract Conv. Mean (SD)	Tract Small Grocery Mean (SD)	Tract Super-market Mean (SD)	1 mile Conv. Mean (SD)	1 mile Small Grocery Mean (SD)	1 mile Super-market Mean (SD)	3 mile Conv. Mean (SD)	3 mile Small Grocery Mean (SD)	3 mile Super-market Mean (SD)	5 mile Conv. Mean (SD)	5 mile Small Grocery Mean (SD)	5 mile Super-market Mean (SD)
Ethnicity													
Hispanic	29.93	2.38a	1.62a	0.73a	4.43a	2.08a	1.13a	12.73a	4.77a	3.39a	14.29a	5.12a	3.71a
		(1.78)	(1.96)	(0.69)	(2.83)	(1.88)	(1.02)	(4.76)	(2.38)	(1.52)	(5.09)	(2.49)	(1.43)
Not Hispanic	70.07	3.67b	0.60b	0.48b	3.29b	0.90b	0.78b	10.76b	2.38b	2.59b	13.39b	2.72b	3.02b
		(2.40)	(1.13)	(0.60)	(2.70)	(1.28)	(0.96)	(7.57)	(2.25)	(2.13)	(8.30)	(2.34)	(2.22)
Education													
< 12 yrs.	34.07	3.23a	1.29a	0.60a	4.02a	1.63a	1.00a	12.04a	3.80a	3.08a	13.96a	4.13a	3.47a
		(2.28)	(1.80)	(0.65)	(2.74)	(1.73)	(1.00)	(6.05)	(2.59)	(1.79)	(6.73)	(2.72)	(1.80)
12 yrs.	39.22	2.53b	0.78b	0.50b	3.42b	1.11b	0.82b	10.60b	2.71b	2.56b	13.04b	3.06b	1.96b
		(1.95)	(1.36)	(0.62)	(2.74)	(1.47)	(0.96)	(7.07)	(2.42)	(2.02)	(7.59)	(2.50)	(2.09)
> 12 yrs.	26.70	2.53b	0.61c	0.58a	3.44b	0.99c	0.84b	11.56a	2.75b	2.92c	14.14a	3.11b	3.31a
		(1.85)	(1.14)	(0.63)	(2.87)	(1.43)	(1.01)	(7.56)	(2.45)	(2.17)	(8.20)	(2.53)	(2.21)
Annual Income													
< $10, 000	31.84	2.73a	0.88a	0.54a	3.68a	1.23a	0.90ab	11.64a	2.94a	2.91a	13.66a	3.24a	3.30a
		(1.95)	(1.48)	(0.62)	(2.72)	(1.58)	(0.99)	(6.85)	(2.48)	(1.98)	(7.74)	(2.61)	(2.06)
$10,000- $15,000	13.82	2.96b	0.84a	0.62b	3.97b	1.23a	0.97a	12.42b	3.17ab	3.10a	14.37b	3.47ab	3.47a
		(1.97)	(1.46)	(0.63)	(2.71)	(1.51)	(0.99)	(6.91)	(2.54)	(1.98)	(8.02)	(2.71)	(2.07)
> $15,000	54.35	2.74a	0.94a	0.54a	3.52a	1.28a	0.86b	10.90c	3.17b	2.72b	13.46a	3.54b	3.12b
		(2.16)	(1.53)	(0.65)	(2.85)	(1.59)	(0.99)	(6.90)	(2.57	(2.02)	(7.20)	(2.61)	(2.02)
Rural Sample (n=2,686)													
Race													
Black	1.34	2.69a	0.67a	0.22a	2.28a	0.47a	0.17a	3.69a	0.67a	0.36a	3.81a	0.67a	0.36a
		(1.80)	(0.86)	(0.42)	(1.83)	(0.65)	(0.38)	(2.76)	(0.76)	(0.49)	(2.82)	(0.76)	(0.49)
Not Black	98.66	2.80a	0.94a	0.32a	2.24a	0.62a	0.22a	3.16a	0.74a	0.39a	3.43a	0.82a	0.41a
		(1.76)	(0.89)	(0.52)	(6.22)	(0.79)	(0.45)	(6.41)	(0.84)	(0.56)	(6.40)	(0.88)	(0.58)
Ethnicity													
Hispanic	11.76	2.79a	1.61a	0.38a	3.76a	0.94a	0.28a	4.33a	1.12a	0.39a	4.45a	1.15a	0.40a
		(1.99)	(0.89)	(0.52)	(14.69)	(1.28)	(0.47)	(14.67)	(1.29)	(0.53)	(14.65)	(1.29)	(0.54)
Not Hispanic	88.24	2.80a	0.91b	0.31b	2.04b	0.57b	0.21b	3.01b	0.68b	0.39a	3.29b	0.77b	0.42a
		(1.73)	(0.89)	(0.52)	(3.79)	(0.69)	(0.44)	(4.15)	(0.76)	(0.56)	(4.15)	(0.80)	(0.58)
Education													

< 12 yrs.	27.33	2.70a	0.95a	0.33a	2.40a	0.67a	0.23a	3.21a	0.78a	0.39a	3.43a	0.85a	0.41a
		(1.84)	(0.88)	(0.53)	(7.65)	(0.87)	(0.46)	(7.79)	(0.93)	(0.57)	(7.78)	(0.95)	(0.58)
12 yrs.	43.86	2.79a	0.94a	0.31a	2.24a	0.63a	0.22a	3.14a	0.75a	0.38a	3.43a	0.85a	0.40a
		(1.65)	(0.87)	(0.51)	(6.10)	(0.80)	(0.43)	(6.27)	(0.83)	(0.54)	(6.27)	(0.88)	(0.56)
> 12 yrs.	28.82	2.91a	0.94a	0.32a	2.10a	0.54a	0.22a	3.16a	0.66b	0.40a	3.43a	0.73b	0.43a
		(1.84)	(0.94)	(0.54)	(4.53)	(0.69)	(0.45)	(4.88)	(0.76)	(0.57)	(4.86)	(0.80)	(0.59)

Individual characteristic	(%)	Tract Conv. Mean (SD)	Tract Small Grocery Mean (SD)	Tract Super-market Mean (SD)	1 mile Conv. Mean (SD)	1 mile Small Grocery Mean (SD)	1 mile Super-market Mean (SD)	3 mile Conv. Mean (SD)	3 mile Small Grocery Mean (SD)	3 mile SM Mean (SD)	5 mile Conv. Mean (SD)	5 mile Grocery Mean (SD)	5 mile Super-market Mean (SD)
Annual Income													
< $10, 000	36.49	0.84a	0.93a	0.32a	2.38a	0.63a	0.23a	3.41a	0.75a	0.41a	3.65a	0.84a	0.43a
		(1.71)	(0.89)	(0.54)	(6.65)	(0.82)	(0.46)	(6.83)	(0.86)	(0.58)	(6.82)	(0.90)	(0.59)
$10,000- $15,000	13.07	2.75a	0.87a	0.31a	2.36a	0.64a	0.23a	3.33a	0.75a	0.41a	3.61a	0.82a	0.44a
		(1.72)	(0.86)	(0.52)	(6.44)	(0.82)	(0.46)	(6.61)	(0.86)	(0.57)	(6.60)	(0.90)	(0.59)
> $15,000	50.45	2.79a	0.96a	0.32a	2.12a	0.60a	0.21a	2.95a	0.72a	0.37a	3.23a	0.79a	0.40a
		(1.80)	(0.91)	(0.51)	(5.74)	(0.77)	(0.43)	(5.95)	(0.83)	(0.53)	(5.94)	(0.86)	(0.56)

Notes: Means within same category followed by different letters are significantly different at the $p < 0.05$ level.

Table 2-5 Availability of convenience stores, grocery stores, and supermarkets by race, ethnicity, income and educational status within a 1-, 3-, and 5-mile radius of WIC cases, by urban influence category (incidence rate ratios from multivariate count regression models)

Individual characteristic	(%)	Tract Con. β (t-value)	Tract Small Grocery β (t-value)	Tract Super-market β (t-value)	1 mile Conv. β (t-value)	1 mile Small Grocery β (t-value)	1 mile Super-market β (t-value)	3 mile Conv. β (t-value)	3 mile Small Grocery β (t-value)	3 mile Super-market β (t-value)	5 mile Conv. β (t-value)	5 mile Small Grocery β (t-value)	5 mile Super-market β (t-value)
Metropolitan Sample (n=12,263)													
Race													
Black	17.28	0.82***	0.93*	0.87**	1.08***	1.53***	1.02	1.27***	1.67***	1.20***	1.29***	1.61***	1.23***
		(79.31)	(2.78)	(8.87)	(24.46)	(289.05)	(0.33)	(1658.09)	(2581.77)	(271.19)	(3820)	(4359)	(763.56)
Ethnicity													
Hispanic	30.47	1.06**	1.28***	1.10**	1.31***	1.93***	1.44***	1.35***	1.78***	1.34***	1.36***	1.54***	1.37***
		(9.81)	(46.17)	(6.80)	(461.60)	(984.17)	(253.63)	(3501.09)	(4180.06)	(940.58)	(7544)	(4429)	(2318.23)
Education													
< 12 yrs.	34.81	0.99	1.03	0.95	1.08***	1.23***	1.00	1.08***	1.20***	1.04***	1.08***	1.14***	1.06***
		(0.75)	(0.82)	(1.85)	(37.70)	(99.07)	(0.03)	(242.21)	(434.55)	(15.28)	(414.52)	(407.47)	(81.32)
> 12 yrs.	41.44	0.99	0.88**	1.08*	1.00	0.82***	1.09**	1.00	0.91***	1.06***	1.00	0.95***	1.05***
		(0.33)	(8.57)	(4.02)	(0.029)	(59.29)	(12.02)	(0.596)	(75.06)	(27.12)	(1.54)	(54.60)	(43.28)
Annual Income													
< $10, 000	34.40	1.03	1.09*	1.03	0.99	1.01	0.99	1.05***	1.01	1.03	1.03***	1.03***	1.03***
		(3.19)	(5.35)	(0.08)	(0.40)	(0.35)	(0.09)	(79.03)	(1.70)	(11.00)	(70.51)	(18.87)	(19.59)
$10,000-$15,000	17.04	1.02	1.06	0.99	1.03	1.06	1.00	1.07***	1.06***	1.07***	1.06***	1.06***	1.07***
		(0.48)	(1.72)	(0.09)	(283)	(6.52)	(0.02)	(119.44)	(27.04)	(40.53)	(196.55)	(66.60)	(90.18)
Micropolitan Sample (n=6,254))													
Race													
Black	5.60	0.89**	0.66***	0.83*	1.05	1.01	1.00	1.15***	1.15***	1.00	1.18***	1.14***	1.03
		(8.43)	(18.23)	(5.61)	(2.57)	(.009)	(.004)	(75.44)	(16.63)	(.003)	(132.60)	(18.50)	(1.11)
Ethnicity													
Hispanic	29.93	1.51***	2.35***	1.63***	1.35***	2.24***	1.46***	1.21***	2.00***	1.34***	1.09***	1.87***	1.25***
		(386.77)	326.69	(234.03)	(385.49)	(1,017)	(149.51)	(469.55)	(1835.72)	(276.29)	(110.04)	(1070)	(178.28)

Individual characteristic	(%)	Tract Con. β (t-value)	Tract Small Grocery β (t-value)	Tract Super-market β (t-value)	1 mile Conv. β (t-value)	1 mile Small Grocery β (t-value)	1 mile Super-market β (t-value)	3 mile Conv. β (t-value)	3 mile Small Grocery β (t-value)	3 mile Super-market β (t-value)	5 mile Conv. β (t-value)	5 mile Small Grocery β (t-value)	5 mile Super-market β (t-value)
Education													
< 12 yrs.	34.07	1.12***	1.23***	1.05	1.07***	1.12***	1.08*	1.08***	1.12***	1.10***	1.05***	1.10***	1.10***
		(28.05)	(18.27)	(1.97)	(19.27)	(18.68)	(5.31)	(65.76)	(45.22)	(28.60)	(32.76)	(35.02)	(28.46)
> 12 yrs.	26.70	1.04	0.88*	1.19***	1.04*	0.97	1.07	1.11***	1.10***	1.18***	1.09***	1.09***	1.15***
		(2.73)	(5.19)	(22.57)	(5.10)	(0.90)	(3.46)	(126.64)	(22.42)	(74.55)	(107.84)	(21.54)	(58.46)
Annual Income													
< $10, 000	31.84	1.06**	1.13*	1.06	1.09***	1.10***	1.12***	1.09***	1.04*	1.12***	1.02**	1.01	1.09***
		(7.65)	(6.73)	(2.88)	(36.33)	(14.51)	(13.16)	(111.62)	(5.17)	(44.29)	(7.33)	(0.40)	(30.63)
$10,000-$15,000	13.82	1.12***	1.03	1.17***	1.17***	1.06	1.19***	1.17***	1.09***	1.18***	1.08***	1.06**	1.14***
		(20.82)	(0.20)	(14.67)	(64.96)	(3.36)	(19.22)	(195.75)	(16.02)	(56.44)	(56.48)	(6.92)	(41.97)
Rural Sample (n=2,686)													
Race													
Black	1.34	0.92	0.76	0.62	1.07	0.81	0.76	1.18	0.95	0.92	1.12	0.85	0.86
		(0.64)	(1.92)	(2.76)	(0.36)	(0.75)	(0.44)	(3.69)	(.057)	(.096)	(1.71)	(0.66)	(0.30)
Ethnicity													
Hispanic	11.76	1.03	1.28***	1.31**	1.93***	1.65***	1.34*	1.53***	1.67***	1.05	1.42***	1.51***	1.00
		(0.37)	(22.48)	(9.91)	(367.72)	(54.27)	(5.81)	(186.18)	(68.81)	(.195)	(135.44)	(46.37)	(0.00)
Education													
< 12 yrs.	27.33	0.96	0.98	0.98	0.94	0.97	1.02	0.95*	0.94	1.01	0.94	0.93	1.00
		(1.86)	(0.14)	(0.06)	(3.48)	(0.31)	(0.05)	(4.41)	(1.13)	(0.03)	(6.62)	(1.83)	(.001)
> 12 yrs.	28.82	1.04	1.02	1.01	0.97	0.88*	1.02	1.03	0.91	1.08	1.02	0.87*	1.08
		(1.85)	(0.19)	(0.02)	(0.76)	(4.26)	(0.03)	(1.63)	(3.02)	(1.05)	(0.56)	(6.70)	(1.07)
Annual Income													
< $10, 000	36.49	1.02	1.01	1.02	1.20***	1.09	1.09	1.21***	1.10	1.13	1.17***	1.10*	1.08
		(0.83)	(0.04)	(0.08)	(41.91)	(2.27)	(0.98)	(63.50)	(3.74*)	(3.05)	(48.03)	(4.12)	(1.17)
$10,000-$15,000	13.07	0.99	0.93	1.01	1.17***	1.10	1.11	1.16***	1.09	1.14	1.15***	1.07	1.11
		(0.14)	(1.53)	(0.004)	(15.44)	(1.57)	(0.69)	(20.79)	(1.35)	(1.80)	(18.23)	(1.01)	(1.29)

Notes: Referent categories are not Black, not Hispanic, 12 years of education, and > $15,000 annual income. Poisson regression estimates for tract level stores include population density of tract as a control. Parameter estimates followed by the symbols *, **, and *** represent statistical significance at the $p < 0.05$, 0.01, and 0.001 level.

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CHAPTER 3 - Spatial availability of supermarkets and the risk of obesity in low-income women varies across the urban-rural continuum

Introduction

Although the prevalence of obesity within the U.S. has increased dramatically across all demographic groups [1, 2], obesity rates among socioeconomically disadvantaged and racial/ethnic minority females are significantly higher as compared to socioeconomically advantaged and white women [3-5]. While the forces contributing to these disparities are complex and operate on multiple levels, a growing body of research suggests that disparities within local food environments may contribute to higher rates of obesity risk observed among vulnerable groups [6-17].

Studies investigating the role of food environments in contributing to unhealthy dietary and weight patterns draw upon a growing body of research reporting a relatively consistent relationship between tract deprivation, high percentages of racial/ethnic minorities, and reduced availability of large grocery stores and supermarkets. Using a national database of food retail outlets, Powell and co-workers [18] reported that low-income neighborhoods had 25% fewer chain supermarkets as compared to more affluent neighborhoods, and that after controlling for neighborhood income, African American neighborhoods had 48% fewer chain supermarkets as compared to white neighborhoods. The association between area disadvantage, minority composition , and reduced access to large grocery stores or supermarkets has also been reported, New Haven, CT [19], Detroit, MI [14], New York City [6, 10], Chicago, Illinois [20] and in rural communities in Minnesota [21].

The mechanism through which retail food environments are hypothesized to impact obesity is through increased availability and lower cost of healthy foods in supermarkets and large grocery stores, as compared to convenience and small grocery stores [22-27]. Studies in both rural [26, 27] and urban [6, 10, 24, 28, 29] areas have reported limited access of healthy food choices at significantly higher prices in convenience as compared to large grocery stores or supermarkets. Reports on healthy food availability and pricing differences in grocery stores versus supermarkets are mixed [19, 20, 26, 30]. Dietary intake studies have reported increased intake of fruits, vegetables, and improved dietary among low-income residents with greater availability of supermarkets [31-34]. In a study focused on dietary intake in women vulnerable to pre-term birth, Laraia [31] reported that living a distance greater than 4 miles from a supermarket was associated with a significant reduction in the dietary quality.

Studies examining the association between proximity to supermarkets and obesity have generally reported parallel relationships, whereby proximity, or residence within the same census tract, as a supermarket is associated with a reduced risk of obesity. Inagami [35] reported that shopping distances in excess of 1.76 miles were associated with a 0.78 unit increase in body mass index (BMI), and that shopping for groceries in tracts of high deprivation was associated with greater BMI. In a four-state study including both urban and rural census tracts, Morland [9], reported that residence in the same tract as a supermarket was associated with a 12% reduction in obesity prevalence, even after adjustment for individual and neighborhood covariates.

However, to date most of the research investigating associations between retail food environments, dietary intake, and obesity have relied upon census tracts or ZIP codes as the appropriate unit of analysis for the food environment exposure, and have been conducted in metropolitan areas. While the use of census tracts as proxies for neighborhood availability is often dictated by data limitation issues [36, 37], the assumption that grocery shopping and retail food environmental exposures are bounded by tracts may be faulty. For instance, in a study in Los Angeles, only 13% of Asians, 15% of blacks, and 23% of whites and Hispanics shopped within their own census tract. Additionally, because the size of census tracts can vary dramatically by sociodemographic composition, the use of census tracts as units of analysis can introduce confounding within urban areas [38]. Lastly, because census tracts are defined largely by population (with an average of 4,000 individuals residing in each tract), tracts are not appropriate units of analysis in sparsely-populated rural areas [39].

This study was initiated to address some of these gaps in the literature on the association between local food environments and obesity. First, by utilizing a statewide, geographically referenced dataset of participants in the Special Supplemental Nutrition

Program for Women, Infants and Children (WIC), in conjunction with a geo-referenced food retail database, we were able to enumerate small grocery stores and supermarkets at the individual level and avoid confounding associated with the use of census tract availability assessments. Because the WIC dataset included BMI measures, we were able to test associations between obesity and store availability among low-income women across the urban-rural continuum, and identify whether these association differed along the urban-rural continuum. The two hypotheses tested in this study included: 1) availability of supermarkets, small grocery stores, and convenience stores would vary by urban influence, with metropolitan WIC participants having greater availability of stores as compared to WIC participants in micropolitan or rural areas; and 2) greater spatial availability of supermarkets would be associated with reduced risk of obesity, after controlling for individual covariates, among the low-income women participating in the WIC Program.

Methods

Study Population

The study population included women who participated in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) between October 10, 2004 and December, 31, 2006. To be eligible for WIC program a participant must be a woman, and a pregnant, breastfeeding, or postpartum mother with children under 5 years of age, and have a household income of < 185% of the federally designated poverty level. Certification in the WIC program is automatic for women and children enrolled in the Supplemental Nutrition Assistance Program (SNAP), Temporary Assistance for Needy Families (TANF), and Medicare programs. However, unlike these federal assistance programs, participation in the WIC program does not require any certification of citizenship. Street addresses and other information from WIC participants were obtained at their certification and post-partum interviews, and collected by the Kansas Department of Health and Environment as part of the Pregnancy Nutrition Surveillance System (PNSS). Variables in the WIC dataset included: race, ethnicity, marital status, age, number of previous pregnancies, education, and household income. Pre-pregnancy BMI was calculated from self-reported pre-pregnancy weight (kg) and height (m) measured at the WIC health clinic at time of enrollment. Post-partum BMI was calculated from height (km) and weight (m) obtained at the first visit post-partum. Pre- and post-pregnancy BMI were highly correlated (Cronbach's α =0.95, $p<0.001$). To avoid confounding due to differences in post-partum certification dates, pre-pregnancy BMI was used as the primary weight outcome measure in the subsequent analyses.

The street address of WIC mothers' home residence was geocoded within ArcGIS (v.9.1 Redlands, CA). The initial list included 25,032 unique cases. The full sample with information eligible for geocoding included 23,351, of which 21,203 (90.8%) were successfully geocoded. There were no significant differences in WIC characteristics by geocoding status. Cases were excluded if the woman was < 18 or > 50 years of age at time of certification, and, and if post-partum BMI was recorded as < 14 or missing. The final sample included 21,166 unique cases. Selected characteristics of WIC are presented in Table 3-1.

Store Classification and Availability

Data on food stores were obtained from the Kansas Department of Agriculture retail food establishment licensure list for 2005. Under Kansas law, all stores selling food items are required to be licensed and inspected to ensure compliance with Kansas Food Code (Kansas Department of Agriculture Food Code, 2005). Store license records included store type based on self-identification in eight categories (bakery, bakery outlet, convenience store, fruit/vegetable market, grocery store, health food store, retail meat store, specialty shop, and variety store), store size (categorized by < 5,000 ft^2, 5,000-15,000 ft^2, > 15,000 ft^2), and physical location (street address). Stores were re-coded using store size and store type into five categories: 1) convenience, 2) small grocery store (< 15,000 ft^2), 3) supermarket (> 15,000 ft^2), 4) specialty store (including bakery, bakery outlet, fruit/vegetable market, health food store, retail meat store and specialty store), and 5) variety store. Stores in the variety category include general merchandise stores (e.g., dollar stores, pharmacies, and general merchandise without a specific grocery section). Super centers with substantial grocery sections (e.g., Wal-Mart Super centers, Target Super centers) were distinguished from general merchandise stores, and classified as supermarkets. Stores were not differentiated based on chain affiliation. For the purposes of this paper, only convenience, small grocery stores, and supermarkets were included in the analyses.

The full listing of retail food stores licensed in 2005 (n=2,680) was geocoded by street address within ArcGIS (v. 9.2 Redlands, CA). A total of 2,520 (94.90%) stores were successfully geocoded to the street address level. Of the stores that were not successfully geocoded (n=160), 73% (n= 116) were convenience stores, 4.4 % (n= 7) were small grocery stores, 6.9% (n= 11), 3.1% (n= 5) were supermarkets, 7.5% (n=12) were specialty stores, and 8.8% (n=14) were variety stores.

Buffers based on Euclidean distances of 1-, 3-, and 5-mile radius from home residence were created for each individual WIC case using the Spatial Analyst Tools within ArcGIS in the North American Datum 1983 (NAD) UTM Zone 14N projection system. Hawth's Analysis Tools (http://www.spatialecology.com/index.php) were used to count the number of stores, by store category, within each of the individual buffers at each specified radius.

Urban Influence

County designations based on metropolitan influence were obtained from USDA-ERS 1983 Urban Influence Codes, which classifies counties based on population, presence of population centers, and adjacency and connectivity to metropolitan areas (USDA-ERS, 1983). The twelve Urban Influence Codes (2 metropolitan UICs and 10 non-metropolitan UICs) were collapsed into three categories: metropolitan (UIC 1,2), micropolitan (UIC 3,5,8) and rural (UIC 4,6,7,9,10,11,12), based on groupings previously identified as relevant to employment and economic patterns in Kansas [40]. This grouping mirrors that utilized by the Office of Management and Budget to designate core-based metropolitan and micropolitan statistical areas (OMB Bulletin 05-02). Metropolitan Statistical Areas include counties with at least one urbanized core of more than 50,000 residents, and adjacent counties that have a minimum of 25% of workers communiting to the central urbanization cluster. Micropolitan Statistical Areas include counties with one population center between 10,000-50,000 residents, and surrounding counties that have a minimum of 25% of workers commuting to the county that includes the urban cluster. Rural areas include counties that do not have an urban cluster of at least 10,000 residents.

Statistical Analyses

All data were reduced and analyzed using SPSS software (v. 15.0, SPSS Inc., Chicago, IL). Differences in store availability by urban influence were assessed by descriptive statistics and one-way analyses of variance. Logistic regression analyses, adjusted for maternal age, parity, race, ethnicity, income, and education, were run to test the associations between urban influence category and risk of obesity. All variables were included in the regression models simultaneously. Logistic regression models were then stratified by urban influence, and the association between race, ethnicity, education, and income were tested, while controlling for maternal age and parity. Stratified and fully adjusted (including adjustment for age, parity, race, ethnicity, education, and income) logistic regression models were run to test the association between presence of a supermarket within a 1-mile radius of residence, mean number of supermarkets, mean number of small grocery stores, mean number of total grocery stores, and convenience stores within a 1-, 3-, and 5-mile radius around each WIC residence.

Results

The number and types of stores available differed in metropolitan, micropolitan, and rural areas (Table 3-2). The number of convenience stores per 10,000 residents was highest in rural areas, with metropolitan and micropolitan areas having 43% and 72% of the convenience stores on a per capita basis as compared to rural areas. Rural areas also had a greater per capita presence of small grocery stores, with 3.43 stores per 10,000 residents as compared to 0.76 and 1.41 stores in metropolitan and micropolitan areas, respectively. Per capita availability of supermarkets was greatest in micropolitan areas with 1.03 supermarkets/10,000 residents. The per capita availability of supermarkets in rural areas was almost half (0.57 supermarkets/10,000 residents) of that observed in metropolitan (0.92 supermarkets/10,000 residents) and micropolitan (1.03 supermarkets/10,000 residents) areas.

Table 3-2 also presents results on the spatial availability of different stores within a 1-, 3-, and 5-mile radius of residence of WIC cases. The majority of WIC cases within Kansas reside within a 1-mile radius of a small grocery store; however, the percentage varied along the urban-rural continuum with 76%, 73% and 60% of metropolitan, micropolitan, and rural cases, respectively, residing in relatively close proximity to a small grocery store. In contrast, spatial availability of supermarkets varied more dramatically along the urban-rural continuum with only 21% of rural WIC cases residing within 1-mile of a supermarket. As radial distance increased, the percentage of rural WIC cases that lived within a 3- and 5-mile radius of supermarkets increased by approximately 16%, reflecting the small number (n=25) of supermarkets identified in rural areas, as compared to metropolitan (n=151) and micropolitan (n=62) areas. In contrast, as radial distance increased within metropolitan and micropolitan areas, the percentage of WIC cases residing within a 5-mile radius of a supermarket increased by 41% in metropolitan areas (98.2% living within a 5-mile radius of a supermarket) and 32% (86.67% residing within a 5-mile radius of a supermarket).

The mean number of convenience, small grocery stores, and supermarkets also varied significantly by urban influence at each radius from WIC residence. The mean availability of convenience stores within a 1-mile radius of WIC residence was greatest among micropolitan cases; however, metropolitan WIC cases had greater exposures to convenience stores at greater distances. A similar pattern was observed for small grocery stores, with micropolitan WIC cases having the greatest number of small grocery stores within 1-mile, and metropolitan WIC cases having more stores at greater radial distances from residence.

Large differences in the prevalence of supermarkets were also observed along the urban-rural continuum, with the greatest prevalence of supermarkets observed at the 1-mile distance in micropolitan areas, and the greatest prevalence at the 3-mile distance observed in metropolitan areas. Differences in supermarket prevalence along the urban-rural continuum increased with increasing radial distance, with rural WIC cases having approximately 25%, 10% and 3% of supermarkets as compared to metropolitan and micropolitan counterparts at 1-, 3-, and 5-mile radial distances.

Odds ratios for obesity are presented in Table 3-3, and reveal a 21% increase in risk of obesity among rural WIC participants (OR=1.21, 95% CI=1.10,1.33), when all individual level covariates are controlled. When stratified by urban influence, black racial status was associated with a 24% increase in obesity risk in the metropolitan sample, but with no significant difference in the micropolitan and rural WIC samples. Hispanic ethnicity was associated with a 18% reduction in obesity risk (OR=0.85, 95% CI=0.77, 0.93) in the metropolitan sample, a 21% (OR=0.79, 95% CI=0.69,0.91) reduction in obesity risk in micropolitan areas, but with no significant difference in obesity risk observed in rural WIC mothers. Low educational status (< 12 years education) was associated with a 12% reduction in obesity risk (OR=0.88; 95% CI=0.80, 0.98) in the metropolitan sample and a 23% reduction in obesity risk (OR=0.77; 95% CI=0.67, 0.89) in the micropolitan sample as compared to WIC mothers who had at least 12 years of education.. Higher levels of education (> 12 years) was associated with increased obesity risk (OR=1.12; 95% CI=1.01, 1.25) within the metropolitan sample, but was associated with a 21% reduction in obesity risk (OR=0.87, 95% CI=0.76, 0.99) within the micropolitan sample. Obesity risk did not differ by educational status in rural WIC participants.

Fully adjusted models testing the associations between obesity and availability of stores within a 1-, 3-, and 5-mile radius are presented in Table 3-4. We chose to test supermarket availability using both a binary measure and mean number of supermarkets in order to determine whether there was a separate protective effect of a supermarket, as compared to having multiple supermarkets at each radius. The presence of a supermarket within a 1-mile radius was associated with an 18% (OR=1.18, 95%CI = 1.05, 1.32) increase in the risk of obesity, and the mean number of supermarkets was associated with a 7% increase in obesity risk (OR=1.07; 95% CI=1.01, 1.14) among micropolitan WIC mothers. Mean number of small grocery stores, total grocery stores, and convenience stores were also associated with increased risk of obesity among micropolitan WIC mothers. Neither the presence or the mean number of supermarkets, small grocery stores, total grocery stores or convenience stores within a 1-mile radius of residence was associated with any change in obesity risk in metropolitan and rural WIC mothers. Mean number of supermarkets within a 3- and 5-mile radius was associated with a slightly reduced risk of obesity within metropolitan WIC cases. No differences in obesity risk were associated with the availability of any type of store, at any radius around WIC residence, within the rural sample.

Discussion

The first hypothesis tested in this study was that the availability of supermarkets, small grocery stores, and convenience stores would vary by urban influence. Consistent with this hypothesis, significant geographic disparities in the availability of grocery stores and supermarkets were observed among low-income women residing in Kansas. Rural WIC participants in Kansas had 74% fewer supermarkets and 55% fewer small grocery stores available within a 1-mile radius as compared to metropolitan WIC cases. The availability of supermarkets and small grocery stores within a 1-mile radius of WIC cases was highest within the micropolitan areas, a result that is consistent with the hypothesis that concentration within the food retail sector, combined with supermarket closure in urban and rural areas, is leading to a grocery store gap within both urban and rural areas [41].

Despite these geographic disparities in small grocery store and supermarket availability, the finding that the majority of WIC participants resided within a 1-mile radius of a grocery store is noteworthy. Previous reports on food store availability have suggested that very rural areas are "food deserts" in which low-income individuals must drive miles to access foods associated with a healthful diet [41-43]. For instance, Blanchard [41] identified approximately 40% of Kansas counties as "severe food desert" counties, in which the proportion of county residents with no access to supermarkets within a 10-mile buffer was much greater than the median for the Midwest region. The contrasting results presented in this study suggest that, at least among low-income women in Kansas, availability of small grocery stores in much better than expected in very rural areas. These results also suggest that low-income women in rural areas are not spatially dispersed, but are instead located within population centers (like county seats) in rural areas. That finding is consistent with those reported by Sharkey [44] in which high deprivation and high minority census block groups had better potential spatial availability of grocery stores and supermarkets within a 6-county rural area in Texas. Given recent reports [42, 45, 46] suggesting that healthy food availability and higher pricing may constrain utilization of these small grocery stores, policies that increase the accessibility of healthy foods at these small stores may be a promising strategy for reducing the higher prevalence of obesity in rural areas [47].

The descriptive results on small grocery store and supermarket availability within metropolitan and micropolitan areas also reveal better than anticipated availability with a 1- and 3-mile radius of WIC cases. In contrast to rural WIC cases, those residing in metropolitan and micropolitan areas have a multiplicity of both small grocery stores and supermarkets to choose from within a relatively small (3-mile) radius of their residence. This finding is consistent with that reported by Rose, in which 76% of Food Stamp recipients had relatively easy access to supermarkets based on car ownership, travel time, and distance to a supermarket [34]. While a 3-mile distance is not realistic when walking with groceries, previous reports from both quantitative and qualitative studies on grocery shopping behavior indicate that most grocery shopping among low-income consumers is performed with a car, sometimes relying on neighbors or family members to transport them to the grocery store [35, 43, 48]. Car ownership by households in high deprivation tracts is 93%, 91%, and 88% in rural, micropolitan, and metropolitan areas of Kansas, respectively. Of course, for individuals who lack access to a vehicle, the relative scarcity of supermarkets within a 1-mile radius would represent a significant barrier to maintaining a healthy diet.

The second hypothesis tested in this study was that the presence of a supermarket within a 1-mile radius, and mean number of supermarkets would be associated with reduced risk of obesity among women participating in the WIC program. In direct contrast to our hypothesis, our results indicate that the presence of a supermarket was not protective against obesity risk in our population of low-income women. Rather, for low-income women residing in micropolitan areas in Kansas, having a supermarket within a 1-mile radius of residence was associated with an 18% increase in obesity risk. The presence of small grocery stores and convenience stores was also associated with an increased risk of obesity among WIC participants who resided in micropolitan areas. A very slight protective effect was associated with the mean number of stores within a 3- and 5-mile radius from residence in metropolitan WIC mothers.

There are several reasons why the results from this study differ from previous studies reporting a protective effect associated with the availability of supermarkets.

First, WIC mothers residing in metropolitan and micropolitan areas had an average of 5.07 and 2.83 supermarkets within a 3-mile radius of their residence, suggesting that choice of supermarket may be a more relevant issue than the mere availability of supermarkets. Secondly, most other studies examining this relationship assessed store availability within the census tract, which because of issues associated with Modifiable Areal Unit Problems (MAUP) may misrepresent the spatial availability of stores, leading to spurious associations. Additionally, using census tract as the unit of analysis may have introduced confounding due to other, unmeasured aspects of the tract that contribute to changes in obesity risk. These potential explanations are consistent with a recent report by Morland [16] in which residence in the same census tract as a supermarket was associated with a significant reduction in obesity risk, but network distance to the nearest supermarket was not associated with a significant reduction in obesity risk.

The finding that increased risk of obesity was associated with greater spatial availability of all types of food stores only within micropolitan areas suggests that level of urbanity may play an important role in mediating the relationship between local food environment and obesity. Micropolitan areas differ in important ways from both metropolitan and rural areas, have different residential and commercial patterns [49, 50], and usually offer an intermediate level of services and economic opportunities [51, 52]. As is apparent from our data on food store availability, micropolitan WIC residents have the highest number of mean convenience, small grocery stores, and supermarkets within a 1-mile radius of their residence. This suggests that most of the WIC participants reside within the urban cluster of the micropolitan areas, and are also likely to be exposed to multiple fast food restaurants and other high caloric density eating opportunities, which are often absent in rural areas. On the other hand, they may also face barriers similar to those faced by residents of rural communities, including lack of sidewalks, concern over traffic, and long commuting times.[53] Research on the association between urban sprawl, land use mix and obesity suggests that micropolitan may have other important features of the built and social environment that contribute to greater obesity risk in these areas [53-57].

Several micropolitan areas within Kansas also have some unique sociodemographic characteristics associated with rapid growth in immigrant populations aligned with the meatpacking industry [58, 59]. Increases in the immigration of Hispanics (and other ethnic minorities) into micropolitan areas have also been observed in other regions of the United States [49]. Dietary acculturation patterns within Hispanic populations suggest that obesity risk is tied to years of residence and other acculturation measures [60-62]. Within the Kansas WIC population, Hispanic ethnicity was associated with reduced obesity risk in micropolitan areas, suggesting that many of the Kansas WIC participants are relatively recent émigrés. The finding that obesity risk is associated with greater store availability in these micropolitan areas has important implications for obesity risk in recently immigrated populations in growing Hispanic communities in micropolitan areas [49, 60, 63, 64]. Future longitudinal research should investigate the role of the micropolitan food environments in the dietary acculturation process associated with increased obesity risk with years of residence in Hispanic women [60, 64] .

There are several limitations of this study that need to be noted. First, due to the cross-sectional nature of our data, no assertions regarding causality can be made. Additionally, retail and residential patterns in Kansas may be unique, and results are not necessarily transferable to highly segregated urban areas [65]. Our measures of store availability were based on number of stores within a radius of WIC residence rather than distance to the closest store, which may have introduced bias into our estimates of availability, particularly in urban areas with significant traffic and in rural areas without dense road networks [66]. However, we chose to examine store availability around a radius of residence because the radial measure better approximates the food environment and most individuals shop at multiple locations [67]. Another limitation is the lack of information on store quality, which has been demonstrated to vary by racial/ethnic and level of deprivation within an area, even within size category of store [28]. However, the literature on store quality generally tends to reveal larger differences between store types (convenience versus grocery) and relatively smaller differences within store categories [24, 29]. Our reliance on publicly available lists of food stores may have also introduced bias toward null associations if stores were misclassified in an undifferentiated manner [44]. Lastly, spatial autocorrelation for residence of WIC cases may have introduced some bias in our associations through reduction in effective sample size [66]. However, unconditional intra-class correlation of BMI associated with residence in census tract was very low (<0.005), indicating that one person's BMI was unlikely to affect another person's BMI in the same neighborhood. Additionally, analysis of spatial autocorrelation of supermarkets within a 1-mile radius of WIC cases indicated that the pattern of supermarkets around WIC cases was neither clustered nor dispersed (Moran's I index = 0.29 at the $p<0.05$ level.)

Most current research in local food environments suggest that lack of spatial availability of healthy foods is the primary link through which structural disparities in local food environments translate to dietary and obesity disparities in disadvantaged populations. However, our data suggest that limited spatial availability may not be the critical issue with our study population in Kansas. The results suggesting that supermarket (and other food retail outlet) availability is associated with increased risk of obesity only among women residing in micropolitan areas is important, and suggests that urban influence moderates the relationship between store availability and obesity. Furthermore, the results indicating that supermarket availability in metropolitan and rural areas was not associated with changes in obesity risk suggests that spatial availability of stores is unlikely to be a primarily structural determinant of eating behaviors leading to obesity. Altogether, these results suggest that future research should focus on testing models that specify spatial (distance to store, density of stores, etc.) measures of availability in conjunction with aspatial measures of accessibility (price, cultural dietary patterns, social patterns, perceptions, etc.) along the urban-rural continuum, within causal pathways that are hypothesized to influence grocery shopping patterns, food choices, and, ultimately, the risk of obesity in vulnerable populations.

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Research conducted in this study was approved by the Kansas State University Institutional Review Board (IRB Approval #4035).

Tables

Table 3-1 Selected characteristics of WIC cases in Kansas (2004-2006)

	Full Sample (n=21,166)		Metropolitan (n=12,247)		Micropolitan (n=6,248)		Rural (n=2,671)	
	%	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD
Race[3]								
White	84.99		78.40		92.38		97.87	
Black	11.83		17.29		5.60		1.35	
All other races[4]	4.21		5.67		2.62		1.27	
Ethnicity								
Not Hispanic	72.02		69.50		70.04		88.24	
Hispanic	27.98		30.50		29.96		11.76	
Previous pregnancies		1.56 (1.73)		1.58 (1.77)		1.51 (1.57)		1.57 (1.87)
Age		24.80 (5.07)		24.94 (5.13)		24.67 (5.02)		24.42 (4.89%)
Education (yrs)		11.46 (2.67)		11.42 (2.67)		11.46 (2.65)		11.61 (2.76)
Monthly Household Income ($)		1,328 (1,611)		1,300 (1,187)		1,375 (1187)		
Body Mass Index								
Pre-pregnancy BMI		26.93 (6.85)		26.88 (6.87)		26.85 (6.61)		27.36 (7.28)
Post-pregnancy BMI		29.30 (6.52)		29.30 (6.59)		29.23 (6.28)		29.48 (6.74)
Obesity Status								
Pre-pregnancy obese (n=5,724)	27.04		26.69		26.41		30.14	
Post-partum obese (n=8,301)	39.22		39.05		38.91		40.73	

[3] Total for race categories (white, black and all other categories) exceed 100% (100.9%) due to multiple races within an individual. Those classified as Hispanic could be designated as any race.

[4] Includes American Indian (n=427), Asian (n=416), and Pacific Islander (n=50) in the full sample. Sample sizes for these races were too small to allow for detailed analyses of other racial categories.

Table 3-2 Stores per 10,00 residents, % of WIC cases with stores in specified radius, and mean store availability available within a 1, 3, and 5 miles radius of residence

	Metropolitan WIC Cases (n= 12,247)	Micropolitan WIC cases (n=6,248)	Rural WIC cases (n=2,671)
Stores per 10,000 residents			
Convenience stores	3.23	5.38	7.45
Grocery stores	0.76	1.41	3.43
Supermarkets	0.92	1.03	0.57
% WIC Cases residing with defined radius of store			
% cases residing within 1 mile radius of convenience store	91.26	83.66	72.30
% cases residing within 1 mile radius of any grocery store	76.23	73.33	60.00
% cases residing within 1 mile radius of supermarket	56.79	54.99	21.04
% cases residing within 3 mile radius of convenience store	97.29	90.99	78.29
% cases residing within 3 mile radius of any grocery store	95.57	89.47	69.71
% cases residing within 3 mile radius of supermarket	92.28	80.57	35.16
% cases residing within 5 mile radius of convenience store	98.22	96.88	82.98
% cases residing within 5 mile radius of any grocery store	97.42	93.82	73.72
% cases residing within 5 mile radius of supermarket	94.44	86.67	37.03
Mean availability of stores within defined radius			
Mean convenience stores in 1 mile radius	2.88a	3.63b	2.24c
Mean grocery stores within 1 mile radius	1.87a	2.14b	0.84c
Mean supermarkets within 1 mile radius	0.84a	0.89b	0.22c
Mean convenience stores within 3 mile radius	17.67a	11.35b	3.17c
Mean grocery stores within 3 mile radius	10.93a	5.93b	1.12c
Mean supermarkets within 3 mile radius	5.07a	2.83b	0.39c
Mean convenience stores within 5 mile radius	36.71a	13.65b	3.43c
Mean grocery stores within 5 mile radius	21.84a	6.66b	1.23c
Mean supermarkets within 5 mile radius	10.83a	3.23b	0.41c

Notes: Supermarkets are defined as grocery stores > 15,000 ft^2. Means within the same row followed by different letters are significantly different at $p < 0.05$ level.

Table 3-3 Adjusted odds ratios for pre-pregnancy obesity for WIC cases for full sample and stratified by urban influence

Individual WIC characteristics	Full Sample β 95% CI	Metropolitan β 95% CI	Micropolitan β 95% CI	Rural B 95 %CI
Metropolitan (n=12,247)	Ref			
Micropolitan (n=6,248)	1.03 (0.96, 1.11)			
Rural (n=2,671)	1.21 *** (1.10, 1.33)			
Black (n=2,504)		1.24*** (1.12,1.39)	1.19 (0.94,1.52)	0.60 (0.27, 1.34)
Hispanic (n=5,922)		0.82*** (0.74,0.91)	0.79** (0.69,0.91)	0.86 (0.65, 1.14)
< 12 yrs. Education (n=7,116)		0.88* (0.80,0.98)	0.77*** (0.67,0.89)	0.82 (0.66, 1.02)
> 12 yrs. Education (n=5,348)		1.12* (1.01,1.25)	0.79** (0.68,0.91)	1.01 (0.83,1.24)
< $10,000 annual income (n=7,164)		0.98 (0.89,1.07)	1.13 (0.99,1.29)	0.95 (0.79, 1.15)
$10,000-$15,000 annual income (n=3,303)		0.96 (0.85,1.07)	1.04 (0.87,1.24)	1.15 (0.89,1.49)

Notes: Unstratified odds ratios adjusted for age, parity, race, ethnicity, education, and income. Odds ratios stratified by urban influence adjusted for age and parity. Reference categories are metropolitan (full sample), non-black, non-Hispanic, 12 years of education, and > $15,000 annual income. Odds ratios followed by *, **, and *** are significant at the p<0.05, p< 0.01, and p< 0.001 level.

Table 3-4 Fully adjusted odds ratios for obesity in WIC mothers in Kansas – Models including availability of grocery stores within 1, 3, and 5 miles of residence

	Metropolitan β (SE) 95% CI	Micropolitan β (SE) 95% CI	Rural β (SE) 95% CI
1 mile supermarket (binary)	0.93 (0.86,1.01)	1.18** (1.05,1.32)	0.99 (0.80,1.22)
1 mile supermarkets (mean)	0.96 (0.91,1.00)	1.07** (1.01,1.14)	0.99 (0.82,1.20)
1 mile small grocery stores	1.01 (0.98,1.04)	1.05* (1.01,1.09)	1.03 (0.92,1.14)
1 mile total grocery stores	1.00 (0.97,1.02)	1.04** (1.01,1.07)	1.02 (0.93,1.12)
1 mile convenience stores	1.01 (0.98,1.03)	1.03* (1.01,1.05)	1.00 (0.99,1.02)
3 mile supermarkets (mean)	0.99* (0.97,0.99)	1.02 0.99, 1.05	0.95 (0.81,1.10)
3 mile small grocery stores	1.00 (0.99,1.01)	1.00 (0.97.1.02)	1.04 (0.94,1.15)
3 mile total grocery stores	1.00 (0.99,1.00)	1.00 (0.99,1.02)	1.01 (0.93,1.10)
3 mile convenience stores	1.00 (0.99,1.00)	1.00 (1.00,1.01)	1.00 (0.99, 1.01)
5 mile supermarkets	0.99* (0.99,0.99)	1.01 (0.98,1.04)	0.94 (0.81,1.09)
5 mile small grocery stores	1.00 (1.00,1.01)	0.99 (0.98,1.01)	1.02 (0.94,1.01)
5 mile total grocery stores	1.00 (1.00,1.01)	0.99 (0.98, 1.01)	1.02 (0.94,1.10)
5 mile convenience stores	0.99 (0.99,1.00)	1.00 (0.99,1.01)	1.00 (0.99,1.02)

Notes: All odds ratios adjusted for age, parity, race, ethnicity, income and education. Standardized regression estimates followed by *, **, and *** are statistically significant at the $p< 0.05$, $p< 0.01$, and $p< 0.001$ level, respectively.

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CHAPTER 4 - Tract deprivation, supermarket availability, and BMI in low-income women across the urban-rural continuum: A multilevel analysis

Introduction

There is a growing consensus that recent dramatic increases in the prevalence of obesity within the U.S. are unlikely due to psychosocial and biological changes at the individual level, but instead are associated with changes in social, economic, and built environments that encourage an imbalance between caloric intake and expenditure among individuals [1-7]. Social ecological theory suggests that the neighborhood is an important domain for investigating these associations [8, 9]. Aspects of the neighborhood environment that have been postulated to affect health include: 1) physical features of the environment (e.g., air and water quality); 2) built environmental resources associated with health (e.g., recreational resources, food stores, restaurants); 3) services associated with health (e.g. medical clinics, educational facilities); 4) sociocultural features (e.g., social capital, community norms); and 5) the reputation of an area [9]. Residence in highly disadvantaged neighborhood environments has been associated with increased mortality and other health outcomes, independent of individual covariates, in a number of studies on neighborhood effects on health [10-14].

The importance of neighborhood context in contributing to increased risk of obesity has been identified in ecological[15] and multilevel studies exploring the relationship between neighborhood characteristics and obesity risk [16-18]. Robert and Reither [19], using data from the America's Changing Lives Study, found that residence in neighborhoods with higher socioeconomic disadvantage was associated with higher BMI, a contextual effect which remained significant even after adjusting for individual level covariates, including age, race, individual SES, physical activity and social support. Similar results highlighting the contextual influence of neighborhood environment on obesity risk were reported by Boardman [20], in which residence in a relatively poor community was associated with an increased risk of obesity, as was residence in an area with a significantly higher prevalence of obesity.

It has been suggested that differences in the neighborhood food environment may be an important link in the causal pathway between neighborhood deprivation and obesity [21-23]. One important feature of the neighborhood food environment is the availability of large grocery stores and supermarkets, which are traditionally associated with greater selection and lower prices of healthy food items [24, 25]. Studies examining disparities in the availability of supermarkets within the U.S. have generally reported significant geographic, ethnic, racial, and socioeconomic disparities in the availability of supermarkets at the level of the census tract or zip code level [26-34]. In a national study on food store availability, Powell [26] reported that rural areas had 14% fewer chain supermarkets, as compared to urban areas, low-income areas (within metropolitan ZIP Codes) had 25% fewer chain supermarkets as compared to intermediate income areas, and that predominantly African American neighborhoods had less than 50% of the chain supermarkets as compared to predominantly white neighborhoods.

Multilevel research investigating the association between local food environments, neighborhood deprivation, and obesity risk within the U.S. have generally found that neighborhood deprivation is positively associated with an increased risk of obesity, and that the presence of a supermarket within a neighborhood is associated with a reduced risk of obesity, after controlling for individual level covariates [35-37]. In a study in Massachusetts, the presence of a supermarket within the same ZIP code tabulation area was associated with a reduced risk of obesity (RR=0.89; 95% CI=0.82, 0.98) [35]. Similarly, Morland reported the presence of a supermarket within the same census tract as residence was associated with a reduced prevalence of obesity (PR=0.83; 95% CI=0.90-0.98) among participants in the Atherosclerosis Risk in Community Study in Mississippi, North Carolina, Maryland, and Minnesota [36]. In contrast, both proximity to supermarkets and a higher density of small grocery stores was associated with increased BMI in a study that included 82 neighborhoods in California [30]. The association between neighborhood deprivation, supermarket availability and BMI was also investigated within metropolitan Los Angeles, CA, but in this study the best predictor of BMI was the neighborhood disadvantage score in which most residents of the area shopped, with shopping in neighborhoods of high disadvantage associated with a net increase of 1.5 BMI units [38].

To date most of the multilevel research examining the associations between neighborhood disadvantage, supermarket availability, and obesity risk have been undertaken within metropolitan areas, and have failed to investigate the impact of urbanity on the association between neighborhood deprivation and obesity. Additionally, few studies have specifically tested whether the presence of a supermarket within the same census tract mediates the relationship between tract deprivation and BMI. This study was undertaken to address some of these noted gaps in the research.

The hypotheses tested in this study include:

1) Tract deprivation is associated with increased BMI, independent of individual level covariates.
2) The association between tract and BMI varies along the urban-rural continuum, with a stronger association in more urbanized areas.
3) The association between tract deprivation and BMI is mediated by the number of supermarkets within a census tract.

Methods

Study Population: Participants in the WIC Program in Kansas

The dataset used in this study included all Kansas mothers enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) between October 10, 2004 and December 31, 2006. Pregnant, breastfeeding, or postpartum mothers with family incomes of < 185% of the federally designated poverty level for family size are eligible for enrollment in the WIC Program. Benefits of the WIC Program include nutrition counseling and education; breastfeeding support and promotion; immunization, health and social services screening and referrals; and coupons that can be redeemed at authorized grocery stores and supermarkets for WIC-approved foods. At the time of this study, WIC approved foods included: milk, cheese, cereal, dry beans, eggs, dry peas, juice, and peanut butter, with an estimated minimum value of $54 a month (KDHE WIC Program Guidelines, 2008).

All information in the WIC dataset was recorded at the initial certification and subsequent WIC Clinic visits, and collected by KDHE as part of the Pregnancy Nutrition Surveillance System (PNSS). Variables in the PNSS used in this study include: mother's age at certification, parity, race, ethnicity, years of schooling, and household monthly income. Pre-pregnancy weight was self-reported, and height was used to calculate pre-pregnancy BMI (kg/m^2). Weight (kg) was measured at the first post-partum visit and used to calculate post-partum BMI. Pre-partum BMI (calculated with self-reported pre-pregnancy weight) and post-partum BMI (objectively measured at first post-partum visit) were highly correlated (Cronbach's $\alpha = 0.95$, $p<0.001$). Due to potential confounding associated with differences in length of time between delivery and first objective weight measurement, pre-pregnancy BMI was used as the primary outcome measure in this study.

The initial study population included 25,032 unique cases, but cases were excluded if the street address of residence were missing or incomplete, and the final sample eligible for geocoding was 23,351. Street address was used to geocode each WIC mother's residence within ArcGIS (v. 9.1, Redlands, CA) using US Street File, with unmatched WIC cases re-matched using a > 30 match score criteria [39]. The final geocoded sample was 21,203 (90.8%). There were no significant differences in WIC characteristics by geocoding status. Cases were excluded from subsequent analyses if the mother was > 50 years of age at the time of certification, and if post-partum BMI was recorded as < 15 or missing. The final sample included 21,166 unique cases. Selected characteristics of WIC mothers in the final sample are presented in Table 1.

Urban Influence

Urban Influence Codes (UIC) for all counties in Kansas were obtained from USDA-Economic Research Service 2003 Urban Influence Code dataset (http://www.ers.usda.gov/Data/UrbanInfluenceCodes/). Urban Influence Codes classify counties based on population density, presence of population centers, and adjacency to metropolitan areas. The twelve UIC's listed in Kansas (2 metropolitan and 10 non-metropolitan) were collapsed into three categories: Metropolitan (UIC 1, 2), Micropolitan (3,5,8) and Rural (UIC 4,6,7,9,10,11,12) based on grouping previously identified as relevant to employment and economic patterns in Kansas [40]. Of the 105 counties in Kansas, 17 (16%) were classified as metropolitan, 19 (18%) were classified as micropolitan, and 69 (66%) were classified as rural.

Tract Deprivation

Census tracts serve as the proxy for neighborhoods in this study. Census tracts were chosen as the administrative unit of analysis because they are contained within a county, have fairly consistent boundaries, and census tract measures of economic deprivation generate health outcomes gradients consistent with those predicted using individual measures [41, 42]. To date, most multilevel research within the U.S. uses census tracts or census block groups as the unit of analysis [43]. A total of 727 census tracts were designated in Kansas in the 2000 Census. Census tracts are contained within county administrative boundaries with fairly consistent boundaries, and originally designated to represent relatively homogeneous population characteristics with an average population of 4,000 individuals within each tract (U.S. Census Bureau, 2000). Census tracts with populations of fewer than 100 individuals (n=7) were excluded from the analysis.

Socioeconomic data at the census tract level were extracted from U.S. 2000 Census SF-3 files, and used to calculate tract deprivation. Tract variables used to calculate tract deprivation included: % adults unemployed and actively seeking work; % adults over 25 years with less than a high school degree; % households under federally designated poverty level; % households with more than one person per room, % female head of household with children; % households with public assistance income; median tract income; and % households with no access to a vehicle. Tract deprivation scores were calculated using maximum likelihood factor analysis with a varimax rotation to maximize score loadings. One factor was identified (Eigenvalue=4.83; Cronbach's α = 0.85) that captured a cumulative 60.83% of variance. Factor item loadings for each variable's contribution to the regression score were: % households below poverty (0.826); % households on public assistance (0.824); % households with no access to a vehicle (0.783); % adults unemployed (0.761); % adults with less than a high school degree (0.755); % female head of household (0.730); median tract income (-0.616) and % households with more than one person per room (0.606). Standardized factor regression scores were calculated for each tract, and tracts were categorized into high, intermediate and low deprivation tertiles. The use of a deprivation index as an indicator of tract socioeconomic status provides a meaningful summary of tract-level conditions while minimizing issues of collinearity associated with many socioeconomic variables [44, 45]. Tract characteristics, including tract deprivation category, are presented in Table 2.

Supermarket and Small Grocery Store Availability

Data on food stores were obtained from the Kansas Department of Agriculture retail food establishment licensure list for 2005. Under Kansas law, all stores selling food items are required to be licenses and inspected to ensure compliance with Kansas Food Code (Kansas Department of Agriculture Food Code, 2005). Store license records included store type based on self-identification in eight categories: bakery, bakery outlet, convenience store, fruit/vegetable market, grocery store, health food store, retail meat store, specialty shop, and variety store. Stores were categorized by size as < 5,000 ft^2, 5,000-15,000 ft^2, and > 15,000 ft^2. For the purposes of this paper, we defined supermarkets as grocery stores (which included Super Centers) that were > 15,000 ft^2. The initial list of retail food stores in Kansas in 2005 included 2,680 total stores, of which 256 were supermarkets. Stores were geocoded within ArcGIS (v. 9.1, Redlands, CA) using street address files, and re-matched using a > 30% matching criteria. Of the 256 supermarkets identified in the list, 244 (95.3%) were successfully geocoded. Stores within each tract were enumerated within ArcGIS using the point in polygon tool.

Statistical Analyses

All data were reduced and statistical analyses were run using SPSS (v. 15.0, SPSS Inc, Chicago, IL). One-way analyses of variance were used to determine difference in store availability by tract deprivation, within both the full and stratified sample. Due to the multilevel nature of our hypotheses and the clustering of WIC mothers within tract, we employed multilevel statistical analyses using mixed model procedures with an unstructured covariance [46]. Multilevel modeling permits an examination of both individual and contextual level variables on an outcome [47, 48]. Multilevel models were run to fit iterative regression models using Maximum Likelihood (ML) estimates, using grand-mean centering for continuous variables, which permits easier interpretation of the regression parameter estimates[46]. The final model estimated fixed effect coefficients for both individual and tract level variables, while adjusting for random intercepts between tracts. The final multilevel model can depicted as:

$$BMI_{ij} = \gamma_{n1}(N_1)j + \gamma_{n2}(N_2) + \ldots\beta_{nk}(N_k)_j + \beta_{i1}(I_i)_{ij} + \beta_{i2}(I)_{ij} + \ldots \beta_{i1}(I_1)_{ij} + \beta_{oj}$$

Tract variables included in the model (depicted by N) included tract deprivation (categorical dummy variables based on tertiles of deprivation scores), supermarkets, small grocery stores and convenience stores in the census tract. Individual level variables (depicted by I) in the final model included: age (mean-centered), parity, race (categorical dummy), ethnicity (categorical dummy), education (categorical dummy) and income (categorical dummy). Because an initial run of the models revealed a significant interaction between urban influence category and tract deprivation (data not shown), subsequent models were stratified by urban influence category. Intra-class correlation was calculated taking the variance associated with the tract level (σ^2_n) and dividing by total variance ($\sigma^2_n / \sigma^2_i + \sigma^2_n$), where σ^2_i represents individual-level variance. Intra-class correlation represents the total variance in outcome that occurs between tracts. Goodness of fit for models was determined using Aikaike Information Criteria, with smaller values indicating better fit.

Results

Characteristics of women participating in the WIC program are presented in Table 4-1. Of the 21,166 women participating in the WIC Program, 57.86% resided in metropolitan counties, 29.52% lived in micropolitan counties, and 12.62% resided in rural counties. The racial composition of WIC participants varied by urban influence, with 78.40% of WIC mothers in metropolitan counties being white, as compared to 92.38% in micropolitan and 97.87% in rural counties. The ethnic composition of WIC cases also varied by urban influence, with 30.50%, 29.96% and 11.76% of WIC mothers in metropolitan, micropolitan, and rural counties designated as Hispanic. The median age of WIC mothers was significantly lower in micropolitan (24.67 ± 5.02) and rural areas (24.42 ± 4.89) as compared to metropolitan areas (24.94 ± 5.13). Mean years of education also varied significantly by urban influence, with rural WIC cases having significantly more years of education (11.61 ± 2.76), as compared to their metropolitan

(11.42 ± 2.67) and micropolitan (11.46 ± 2.65) counterparts. Metropolitan WIC mothers had significantly less monthly income ($1,300 ± 1,187), as compared to micropolitan ($1,375 ± 1,187) and rural ($1,346 ± 1,487) WIC mothers. Mean previous pregnancies was higher in metropolitan (1.58 ± 1.77) and rural (1.57 ± 1.87), as compared to micropolitan (1.51 ± 1.57) WIC mothers.

Rural WIC cases had a mean pre-pregnancy BMI of 27.36 (SD=7.28), which was significantly higher than metropolitan (26.88 ± 6.87) and micropolitan WIC cases (26.85 ± 6.61). Post-pregnancy BMI did not vary by urban influence, reflecting significant variation in the time between giving birth and first post-partum certification by urban influence.

Within the overall WIC population, 33% of WIC mothers had 12 years of schooling, which is usually the equivalent of a high school degree. The percentage of WIC mothers with a high school degree varied across the urban-rural continuum, with a significantly higher percentage of rural WIC mothers having at least a high school degree, as compared to metropolitan or micropolitan WIC mothers. Income level also varied by urban influence, with 54.27% of micropolitan WIC mothers having an annual household income of at least $15,000, as contrasted to 50.54% in rural areas and 48.60% in metropolitan areas. The highest percentage of mothers in the lowest income category (< $10,000) was observed in rural areas. However, it is important to remember that within our WIC sample, all participants had household incomes < $185% of the federally-defined level for household size.

The percentage of WIC mothers who resided in high deprivation tracts varied widely across the urban-rural continuum, with the highest percentage of WIC mothers residing in high deprivation tracts in metropolitan areas (64.96%), as compared to metropolitan areas (59.30%) and rural areas (39.39%). Micropolitan areas also had the lowest percentage of WIC mothers residing in low deprivation tracts (8.10%) as compared to rural (8.69%) and metropolitan (18.05%) areas.

Mean store availability differed significantly by tract deprivation across the urban-rural continuum (Table 4-3). Within metropolitan tracts, the number of supermarkets available within tract did not vary by tract deprivation, but there were significantly fewer small grocery stores and convenience stores in low deprivation tracts as compared to high deprivation tracts. Within micropolitan areas, convenience stores were the only store type to differ significantly by deprivation, with significantly more convenience stores in high deprivation tracts as compared to low and intermediate deprivation categories. Within rural areas, both high and low deprivation tracts had significantly fewer small grocery stores, as compared to intermediate level deprivation tracts. There were no differences in supermarket availability by tract deprivation in the rural sample, but low deprivation tracts had significantly fewer convenience stores as compared to intermediate and high deprivation tracts.

Multilevel, multivariate analysis with BMI regressed on both individual level predictors (race, ethnicity, education, and income) and contextual predictors (store availability and neighborhood deprivation) are presented in Table 4-4 through 4-6. Overall, nesting within census tract accounted for very little variance in any of our samples (Model 1). The estimated variance associated with tract among metropolitan WIC cases was .4% (unconditional intraclass correlation = 0.004), as compared to 0.5% (ICC=0.005) in micropolitan and an undetectable amount in rural WIC cases. Introducing tract deprivation into our models (Model 2) reduced the percentage of variance associated with nesting in tracts by 50% in our metropolitan sample and by 60% in our micropolitan sample.

The association between tract deprivation varied by urban influence (Model 2). Within our metropolitan sample, deprivation was linearly associated with BMI with a 0.524 unit increase in BMI associated with intermediate deprivation, and a 0.840 unit increase associated with residence in a high deprivation tract as compared to residence in a low deprivation tract. The association between tract deprivation in micropolitan areas was not linear, with no significant difference in BMI between residents in high deprivation and low deprivation tracts, and a decrease of 0.738 BMI unit associated with residence in an intermediate deprivation tract. There was no association between tract deprivation and BMI among WIC women in rural areas.

The presence of supermarkets, small grocery stores, and convenience stores did not mediate the association between tract deprivation and BMI in any of the areas along the urban-rural continuum (Models 3-5). The addition of tract deprivation did reduce the association between black racial status and BMI from 1.06 BMI units to 0.934 BMI units within the metropolitan sample. In contrast, the inclusion of tract deprivation in our fully adjusted model (model 7) increased the association of low educational attainment with BMI among both micropolitan and rural WIC mothers.

Individual level predictors are presented in Model 6 within each table. Within metropolitan WIC mothers, black ethnicity was associated with a 1.06 unit increase in BMI, while Hispanic ethnicity was associated with a –0.464 unit increase in BMI. Within the micropolitan sample, the only individual level predictor that was significant was educational status, with WIC mothers with less than a high school degree having a –0.771 unit BMI decrease as compared to mothers who had completed at lease 12 years of education. None of the individual level characteristics within the rural WIC population were predictive of BMI.

Discussion

The hypothesized association between high tract deprivation and BMI was observed within WIC mothers residing in metropolitan areas. Among WIC mothers who lived in metropolitan areas, women who lived in intermediate and high deprivation tracts had a 0.622 unit and 0.937 unit increase in BMI, respectively, after controlling for individual demographic characteristics, as compared to women who lived in low deprivation tracts. In contrast to other studies examining the relationship between tract deprivation and BMI [19, 20], the effects associated with deprivation are larger; however, the increased effect may be due to the fact that our sample consisted solely of low-income women. The deprivation-amplification process, as described by Macintyre and co-workers [9], suggests that the poor quality environments associated with high deprivation neighborhoods amplify the effect of disadvantages experienced at the individual level on health outcomes.

In contrast to the results obtained in metropolitan areas, BMI was not linearly associated with BMI in micropolitan areas. Within micropolitan areas, BMI within the intermediate tracts, when controlling for individual level covariates, was significantly lower than BMI observed in both low deprivation and high deprivation tracts. These differences may be due to the unique characteristics of micropolitan areas. Micropolitan areas are characterized by the presence of a small town (10,00-50,000 population), serve as regional commercial centers, and may have unique characteristics associated with the "rural suburbanization" process [49]. The spatial distribution of low-income residents is also likely to differ in micropolitan areas, as compared to the concentration of low-income residents observed in metropolitan areas and diffuse patterns of residence as seen in sparsely population areas [50].

No association between tract deprivation and BMI was observed in rural areas. This finding is not unexpected due to the fact that rural tracts are quite large, and can comprise the entire county. Thus, any environmental features associated within tract in our stratified sample are unlikely to have a significant influence on individual BMI. It is important to note, however, that in Chapter Two we report that residence in a rural area, independent of individual covariates, is associated with a 21% increase in risk of obesity among WIC participants (OR=1.21, 95% CI=1.10, 1.33). Increased risk of obesity associated with rural residence has been reported in other studies within the U.S. [51, 52].

The second hypothesis tested in this study, that the association between tract deprivation and BMI would diminish as we moved along the urban-rural continuum, yielded somewhat unexpected results. This hypothesis was developed based on the growing literature on neighborhood effects in health, in which residence in high deprivation areas is generally associated with poorer health outcomes [9]. Within this literature, neighborhoods are generally defined as shared geographic spaces in which people interact [53], with shared physical, cultural and economic attributes that can influence dietary intake and caloric expenditure associated with obesity outcomes [54]. The use of census tract as a proxy for neighborhood is well-established in most health literature [17, 55]. However, due to the relatively larger size of tracts in non-urban areas, the utility of the census tract as a proxy for neighborhoods in micropolitan and rural areas is less clear [56]. The hypothesis that the association between tract deprivation and BMI would diminish as we moved from metropolitan to rural areas was based on the concept that the influence of neighborhood characteristics on individual behaviors would diminish as we increased the spatial scale of neighborhoods. If this relationship was linear, we would expect to find that associations between tract deprivation and BMI would be highest in metropolitan areas, intermediate in micropolitan areas, and limited or non-existent in rural areas.

Contrary to our original hypothesis, we found a non-linear association between tract deprivation and BMI in micropolitan areas, suggesting that the nature of this relationship may be unique in micropolitan areas, as opposed to just being attenuated as we move from metropolitan to micropolitan contexts. The finding that tract deprivation was not associated with BMI in rural areas was unsurprising given the large geographic extent of census tracts in rural areas, and the distal nature of any "neighborhood" effects seen in these regions. However, in contrast to micropolitan areas, the trends in the association between tract deprivation and BMI were in the expected direction in rural areas, with women residing in higher deprivation tracts having higher (but not statistically significant) BMI as compared to those in lower deprivation tracts.

The availability of grocery stores and supermarkets within census tracts has been suggested as an important feature of neighborhoods that mediate the relationship between tract deprivation and obesity [19, 57], particularly among women [58]. The third hypothesis tested in this study examined whether the presence of supermarkets, small grocery stores, and convenience stores within a census tract was associated with BMI, independent of individual-level covariates and tract deprivation. The number of supermarkets, small grocery stores, and convenience stores within a census tract was not associated with any significant change in BMI in any of the multi-level models examined in this study.

The results that store availability within census tract are not associated with BMI changes, independent of individual-level covariates and tract deprivation, among the low-income women in our study highlight the need for greater elucidation of the hypothesized causal pathways associated neighborhood characteristics and obesity. To date, most research has suggested that neighborhood availability of supermarkets, by increasing the availability and accessibility of foods associated with healthy diets, have a direct protective effect against obesity [54]. In contrast, the results obtained in this study suggest that the neighborhood effect of supermarket availability does not lie directly on the causal pathway between neighborhood deprivation and obesity risk. This finding has important implications for potential policy interventions focused on increasing the neighborhood availability of supermarkets. If supermarket availability does not directly mediate the association between tract deprivation and obesity, the siting of supermarkets within high deprivation tracts is not likely to have an effect on the prevalence of overweight and obesity within the neighborhood. Natural experiments undertaken in the U.K. in which large supermarkets have been sited in high deprivation tract suggest that the dietary impacts of these interventions are minimal [59, 60] or null [61, 62].

It is important to note, however, the finding that supermarkets availability does not mediate the relationship between tract deprivation and BMI in metropolitan areas should not be construed to mean that local food environment does not play a role in stratification of obesity risk in vulnerable populations. Rather, we would suggest that the complex interactions between food environment and obesity risk are not suited for cross-sectional studies such as this one. The effects of the food environment on obesity risk are likely to accrue over the lifecourse, suggesting a need for longitudinal analyses to examine these relationships. Furthermore, the relationships between food environments and individual behaviors are bi-directional and recursive, suggesting the need for post-structural approaches to these relationships. Future research should examine the utility of post-structural frameworks, such as reproduction theory as proposed by Bourdieu [63, 64] and class structuration theory as proposed by Giddens [65, 66]. Methodological approaches that show promise for use in post-structural frameworks include dietary mapping [67] and structural equation and path-analysis modeling [23, 68, 69].

In addition to the cross-sectional nature of this study which prohibits any attribution of causation, several other limitations of this study must be noted. First, this study only examined the association of deprivation, supermarket availability, and BMI among low-income participants in the WIC program in Kansas. It is expected that if this study were expanded to include a wider range of women from a wider range of socioeconomic positions, that we would see stronger individual level effects associated with BMI. Second, we relied on a statewide, historical database of food stores available in 2005. While previous studies report high reliability of these databases [70], studies employing ground-truthing in rural areas suggest some misclassification of stores [71]. Additionally, we did not characterize stores by quality, and some studies have found significant differences in the quality of stores by tract deprivation [27]. However, differences in the availability and pricing of healthy foods are likely to be more significant between store categories (supermarket vs. convenience store), as compared to differences in these attributes within store category. Lastly, store availability within a census tract may misrepresent actual spatial availability of stores due to differences in tract size and the availability of stores in nearby census tracts.

Despite these limitations, this study provides important insight into the relationships between tract deprivation, supermarket availability and BMI among low-income women. As expected, tract deprivation was associated with increased BMI among low-income women in our study. The finding that tract deprivation was not linearly associated with BMI in micropolitan areas is noteworthy, suggesting that urban influence may play an important role in moderating the relationship between tract characteristics and obesity. Lastly, the finding that the presence of supermarkets does not mediate the relationship between tract deprivation and obesity in metropolitan areas is critical, suggesting that future research should focus on elucidating the complex and recursive associations between area socioeconomic disadvantage and dietary outcomes.

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Research conducted in this study was approved by the Kansas State University Institutional Review Board (IRB Approval #4035).

Tables

Table 4-1 Selected characteristics of WIC Mothers in Kansas (2004-2006)

	Full Sample (n=21,166)		Metropolitan (n=12,247)		Micropolitan (n=6,248)		Rural (n=2,671)	
	(%)	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD	N (%)	Mean ± SD
Race/Ethnicity[5]								
White	84.99		78.40		92.38		97.87	
Black	11.83		17.29		5.60		1.35	
All other races[6]	4.21		5.67		2.62		1.27	
Hispanic	27.98		30.51		29.96		11.76	
Marital Status								
Unmarried	61.18		65.09		56.35		54.51	
Married	38.82		34.91		43.65		45.49	
Age		24.80		24.94		24.67		24.41
		5.07		5.13		5.02		4.89
Weight Status								
Pre-pregnancy BMI		26.93		26.88		26.85		27.37
(self-report)		6.85		6.87		6.61		7.28
Post-partum BMI		29.30		29.30		29.23		29.48
(objective)		6.52		6.59		6.28		6.74
Education								
<12 yrs. schooling	33.62		34.78		34.06		27.26	
12 yrs. schooling	41.11		41.47		39.23		43.88	
> 12 yrs. schooling	25.27		23.74		26.71		28.87	
Annual Household Income								
< $10,00	33.85		34.33		31.82		36.35	
$10,000-$15,000	15.61		17.07		13.81		13.10	
>$15,000	50.55		48.60		54.37		50.54	
Tract Characteristics								
Low tract deprivation	13.93		18.05		8.10		8.69	
Intermediate tract deprivation	27.60		22.63		26.94		51.93	
High tract deprivation	58.46		59.30		64.96		39.39	

[5] Race and ethnicity were included into one category; however, these items were asked separately on WIC intake forms. Total for race categories (white, black and all other categories) exceed 100% (100.9%) due to multiple races within an individual. Those classified as Hispanic could be designated as any race.
[6] Includes American Indian (n=426), Asian (n=416), and Pacific Islander (n=50) in the full sample. Sample sizes for these races/ethnicities were too small to allow for detailed analyses of other racial/ethnic categories.

Table 4-2 Selected characteristics of census tracts in Kansas

	N	%	Minimum	Maximum	Mean ± SD
Metropolitan Tracts	422	58.6			
2000 population	1,644,269	72.25	126	11,598	3,896 ± 1,787
Land Area (miles^2)	11,064	13.53	0.19	756.71	26.22 ± 74.54
Population Density (persons/km^2)			6.46	11,185.11	2,407 ± 1,990
Lowest tertile deprivation	187	44.3			
Intermediate tertile deprivation	90	21.3			
Highest tertile deprivation	145	34.4			
Supermarkets in tract			0	4	0.36 ± 0.607
Micropolitan Tracts	148				
2000 population	603,665	26.21	1,430	11,445	4,078 ± 1,769
Land Area (miles^2)	15,339	18.75	0.48	1,182	104 ± 182
Population Density (persons/miles^2)			3.82	8,139	1,082 ± 1,550
Lowest tertile deprivation	27	18.2			
Intermediate tertile deprivation	57	38.5			
Highest tertile deprivation	64	43.2			
Supermarkets in tract			0	2	0.42 ± 0.60
Rural Tracts	150				
2000 population	440,461	19.12	1,178	6,152	2,936 ± 1,088
Land Area (miles^2)	55,395	67.72	1.40	1,072	369.3 ± 319
Population Density (persons/miles^2)			1.35	2,205	76.57 ± 209
Lowest tertile deprivation	21	14.0			
Intermediate tertile deprivation	96	64.0			
Highest tertile deprivation	33	22.0			
Supermarkets in tract			0	2	0.17 ± 0.41

Source: U.S. Census Bureau, 2000.

Table 4-3 Mean convenience stores, small grocery stores, and supermarkets by tract deprivation

	Convenience Stores Mean ± SD	Small Grocery Stores Mean ± SD	Supermarkets Mean ± SD
Full Sample (n=720)			
Lowest tertile tract deprivation (n=235)	1.17a ± 1.29	0.30a ± 0.64	0.39a ± 0.66
Intermediate tertile deprivation (n=243)	1.53b ± 1.55	0.66b ± 0.86	0.27a ± 0.51
Highest tertile deprivation (n=242)	1.83b ± 1.58	0.54b ± 0.88	0.33a ± 0.54
Metropolitan Sample (n=422)			
Lowest tertile tract deprivation	1.04a ± 1.26	0.20a ± 0.55	0.43a ± 0.68
Intermediate tertile deprivation	1.70b ± 1.43	0.33b ± 0.54	0.31a ± 0.55
Highest tertile deprivation	1.26a ± 1.18	0.39b ± 0.70	0.29a ± 0.51
Micropolitan Sample (n=148)			
Lowest tertile tract deprivation (n=27)	1.63a ± 1.39	0.44a ± 0.75	0.30a ± 0.61
Intermediate tertile deprivation (n=57)	1.95a ± 1.27	0.42a ± 0.71	0.40a ± 0.56
Highest tertile deprivation (n=64)	2.66b ± 1.90	0.77a ± 1.21	0.48a ± 0.62
Rural Sample (n=150)			
Lowest tertile tract deprivation (n=21)	1.67a ± 1.20	0.95a ± 0.80	0.14a ± 0.36
Intermediate tertile deprivation (n=96)	2.13b ± 1.78	1.10b ± 0.99	0.15a ± 0.41
Highest tertile deprivation (n=33)	2.70b ± 1.36	0.76b ± 0.71	0.24a ± 0.44

Notes: Means followed by different letters within columns are different at the $p < 0.05$ level using Games-Howell post hoc analyses.

Table 4-4 BMI regressed on neighborhood deprivation, urban influence, age, race, ethnicity, parity, education and income of WIC mothers in metropolitan Kansas (n= 12,247)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Fixed effects							
Tract Deprivation							
High deprivation		0.840	0.840***	0.827***	0.855***		0.937***
		0.17	(0.17)	(0.17)	(0.17)		(0.17)
Intermediate deprivation		0.524	0.517*	0.519-	0.491*		0.622**
		0.20	(0.21)	(0.20)	(0.20)		(0.20)
Tract Supermarkets			-0.034				
			(0.10)				
Tract Small Grocery Stores				0.133			
				(0.10)			
Tract Convenience Stores					0.092		
					(0.05)		
Race							
Black						1.06***	0.934***
						(0.17)	(0.17)
Ethnicity							
Hispanic						-0.239	-0.331
						(0.15)	(0.15)
Education							
< HS Degree						-0.464***	-0.504**
						(0.15)	(0.15)
> HS Degree						0.376	0.432**
						(0.16)	(0.16)
Annual Income							
< $10,000						0.035	0.026
						(0.14)	(0.14)
$10,000-$15,000						-0.044	-0.053
						(0.17)	(0.17)
Intercept	0.077	-0.538***	-0.519**	-0.571***	-0.677***	-6.105***	-6.749***
	0.07	(0.15)	(0.16)	(0.15)	(0.17)	(0.34)	(0.37)
Random Effects							
Level 2 variance	0.189*	0.087	0.091	0.093	0.079	0.221*	0.093
τ^2_0 = var (U_{ij})	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)	(0.10)	(0.08)
Level 1 variance	46.950***	46.600***	46.959***	46.951	46.956***	44.696***	44.712
σ^2_0=(R_{ij})	(0.60)	(0.60)	(0.60)	(0.60)	(0.60)	(0.58)	(0.58)
Interclass correlation	0.004	0.002	0.002	0.002	0.002	0.005	0.002
AIC	81945.42	81913.74	81916.35	81910.70	81914.45	81366.90	

All models adjusted for age and parity. Reference categories are not low tract deprivation, not black, not Hispanic, high school degree (12 yrs education), and >$15,000 annual income.
Estimates followed by the symbols *, ** and *** are significant at p<0.10, p<0.05, and p<0.01 level, respectively.
Model descriptions:
Model 1 – Unconditional means model
Model 2 – Tract level (level 2) variance in BMI explained by tract deprivation
Model 3 – Tract level (level 2) variance in BMI explained by tract deprivation and supermarket
Model 4 – Tract level (level 2) variance in BMI explained by tract deprivation and small grocery stores.
Model 5 – Tract level (level 2) variance in BMI explained by tract deprivation and convenience stores
Model 6– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables)
Model 7– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables) and tract deprivation (level 2 variable)

Table 4-5 BMI regressed on neighborhood deprivation, urban influence, age, race, ethnicity, parity, education and income of WIC mothers in micropolitan Kansas (n=6,248)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Fixed effects							
Tract Deprivation							
High deprivation		-0.066	-0.078	-0.053	-0.045		0.035
		(0.32)	(0.32)	0.32	(0.33)		(0.32)
Intermediate deprivation		-0.738*	-0.762	-0.731*	-0.728*		-0.686***
		(0.35)	(0.35)	(0.35)	(0.35)		(0.34)
Tract Supermarkets			0.148				
			(0.14)				
Tract Small Grocery Stores				-0.128			
				(0.07)			
Tract Convenience Stores					-0.175		
					(0.047)		
Race							
Black						0.656	0.596
						(0.36)	(0.36)
Ethnicity							
Hispanic						-0.181	-0.268
						(0.21)	(0.21)
Education							
< HS Degree						-0.771***	-0.793***
						(0.20)	(0.20)
> HS Degree						-0.312	-0.287
						(0.21)	(0.21)
Annual Income							
< $10,000						0.223	0.223
						(0.19)	(0.19)
$10,000-$15,000						0.093	0.090
						(0.25)	(0.25)
Intercept	0.051	0.302	0.237	0.304	0.334	-5.45***	-5.24***
	(0.10)	(0.30)	(0.31)	(0.31)	(0.32)	(0.47)	(0.55)
Random Effects							
Level 2 variance	0.218	0.096	0.113	0.120	0.115	0.251	0.137
τ^2_0 = var (U_{ij})	(0.15)	(0.13)	(0.14)	(0.14)	(0.14)	(0.15)	(0.14)
Level 1 variance	43.479***	43.514***	43.50***	43.502***	43.505***	41.502	41.520
σ^2_0=(R_{ij})	(0.79)	(0.79)	(0.79)	(0.79)	(0.79)	(0.75)	(0.75)
Interclass correlation	0.005	0.002	0.003	0.003	0.003	0.006	0.003
AIC	41332.69	41323.76	41324.76	41327.27	41327.91	41055.53	41045.51

All models adjusted for age and parity. Reference categories are not low tract deprivation, not black, not Hispanic, high school degree (12 yrs education), and >$15,000 annual income.
Estimates followed by the symbols *, ** and *** are significant at p<0.10, p<0.05, and p<0.01 level, respectively.
Model descriptions;
Model 1 – Unconditional means model
Model 2 – Tract level (level 2) variance in BMI explained by tract deprivation
Model 3 – Tract level (level 2) variance in BMI explained by tract deprivation and supermarket
Model 4 – Tract level (level 2) variance in BMI explained by tract deprivation and small grocery stores.
Model 5 – Tract level (level 2) variance in BMI explained by tract deprivation and convenience stores
Model 6– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables)
Model 7– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables) and tract deprivation (level 2 variable)

Table 4-6 BMI regressed on neighborhood deprivation, urban influence, age, race, ethnicity, parity, education and income of WIC mothers in rural Kansas (n=2,671)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Fixed effects							
Tract Deprivation							
High deprivation		0.347	0.334	0.346	0.407		0.786
		(0.53)	(0.53)	(0.53)	(0.53)		(0.52)
Intermediate deprivation		-0.145 (0.52)	-0.179 (0.52)	-0.205 (0.52)	-0.095 (0.53)		0.051 (0.51)
Tract Supermarkets			-0.327 (0.27)				
Tract Small Grocery Stores				0.198 (0.16)			
Tract Convenience Stores					-0.059 (0.08)		
Race							
Black						-0.559	-0.62
						(1.20)	(1.19)
Ethnicity							
Hispanic						-0.083	-0.121
						(0.45)	(0.45)
Education							
< HS Degree						-0.579	-0.573
						(0.35)	(0.34)
> HS Degree						0.391	0.433
						(0.34)	(0.34)
Annual Income							
< $10,000						-0.043	-0.060
						(0.31)	(0.31)
$10,000-$15,000						0.166	0.089
						(0.43)	(0.43)
Intercept	0.563***	0.502	0.629	0.347	0.618	-6.74***	-7.167***
	(0.14)	(0.48)	(0.49)	(0.49)	(0.50)	(0.80)	(0.92)
Random Effects							
Level 2 variance						0.139	50.64
τ^2_0 = var (U_{ij})						0.29	(1.39)
Level 1 variance	53.025***	53.01***	53.00***	53.00***	53.019***	50.601***	50.640***
σ^2_0=(R_{ij})	(1.45)	(1.45)	(1.45)	(1.45)	(1.45)	(1.41)	(1.39)
Interclass correlation						0.003	
AIC	18190.97	18188.35	18187.66	18188.64	18190.99	18072.32	18065.94

All models adjusted for age and parity. Reference categories are not low tract deprivation, not black, not Hispanic, high school degree (12 yrs education), and >$15,000 annual income.
Estimates followed by the symbols *, ** and *** are significant at p<0.10, p<0.05, and p<0.01 level, respectively.
Model descriptions;
Model 1 – Unconditional means model
Model 2 – Tract level (level 2) variance in BMI explained by tract deprivation
Model 3 – Tract level (level 2) variance in BMI explained by tract deprivation and supermarket
Model 4 – Tract level (level 2) variance in BMI explained by tract deprivation and small grocery stores.
Model 5 – Tract level (level 2) variance in BMI explained by tract deprivation and convenience stores
Model 6– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables)
Model 7– BMI predicted by age, parity, race, ethnicity, income, and education (level 1 variables) and tract deprivation (level 2 variable)

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Dissertation Conclusions

The primary aim of this dissertation is to investigate the associations between the local food environment and obesity among low-income women across the urban-rural continuum in Kansas. This aim was achieved by developing a set of testable hypotheses derived from a review of the relevant research literature (Chapter One), and then testing these hypotheses in a series of inter-related research studies utilizing a large, surveillance dataset of women participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) combined, within a geographic information system (GIS), with a geo-referenced dataset of supermarkets, small grocery stores, and convenience stores in Kansas (Chapters 2-4).

The study population (participants in the WIC program) for this research was selected because low income and food insecurity are associated with increased risk of obesity in women [1-3]. While there are many factors that operate (and interact) at multiple levels across the life-course that influence risk of obesity, ecological theories of health behavior suggest that disparities in health promoting features in low-income neighborhoods might contribute to disparities in obesity experienced by low-income and minority women [4]. Furthermore, because neighborhoods contexts are also affected by larger regional social, economic and demographic characteristics, it is likely that these neighborhood features may also differentially affect obesity risk across the urban-rural continuum.

The first chapter of this dissertation identified three testable hypothesis associated with the overall question of whether geographical, ethnic, racial and socioeconomic disparities in the prevalence of obesity are related to disparities in neighborhood retail food environments. The specific hypotheses identified included: 1) geographic differences in the access and availability of foods result in disparities in the retail environment; 2) neighborhoods of low socioeconomic status with high concentrations of racial and ethnic minorities have limited availability of healthy foods; and 3) individuals who are exposed to poor-quality food environments are more likely to have diets that include foods of low nutritional quality and high caloric density, and higher rates of obesity. Studies reviewed in this chapter suggested that there was considerable support for the first two hypotheses regarding disparities in the food environment, but less support for the third hypothesis due to the lack of multilevel studies that investigated the contextual effect of food environments while controlling for individual level covariates. Most importantly, this chapter identified key gaps in the literature, including studies that examined the relationship between store availability and obesity in rural areas, and studies that examined this relationship using individual-level estimates of food store availability.

Chapter Two examined geographic, racial, and ethnic disparities in the availability of supermarkets and grocery stores among low-income women across the urban-rural continuum in Kansas. One important aim of this chapter was to determine whether availability estimates and associations with sociodemographic characteristics observed at the tract level followed the same patterns of those observed when examining store availability in a 1-mile radius around residence. This is an important question because if availability and associational measures differ when examining relationships with different units of analysis, any subsequent associations between supermarket availability and obesity may be biased [5]. In fact, our results from this analysis indicate that estimates of availability and associations with sociodemographic characteristics of WIC mothers did differ, and that racial, ethnic and socioeconomic disparities in supermarket availability observed at the tract level were not mirrored when we examined disparities in food store availability in a 1-mile radius around the home residence of WIC mothers. These results highlight the importance of addressing Modifiable Areal Unit Problems (MAUP) in studies that examine the associations between local food environments and dietary outcomes.

A second important finding in this chapter was that among low-income women participating in the WIC program, racial/ethnic minorities and WIC mothers with very low incomes and educational status had equal or greater availability of supermarkets and grocery stores, as compared to white, non-Hispanic, and WIC mothers of higher income and educational status. This finding suggests that supermarket interventions in metropolitan areas designed to address obesity among vulnerable groups in low-income areas may have limited impact. However, significant geographic disparities in the availability of supermarkets and small grocery stores were observed among WIC mothers residing in rural areas, with rural WIC residents having only 25% of the supermarkets within a 1-mile radius as compared to metropolitan and micropolitan WIC mothers.

The association between the availability of supermarkets, small grocery stores and obesity were investigated in Chapter Three. Contrary to our original hypothesis, the presence of nearby supermarkets did not provide any protective effect against obesity among low-income women across Kansas. This finding, combined with the results indicating that WIC mothers in metropolitan and micropolitan areas have a multiplicity of supermarkets available within a 3-mile radius, suggest that lack of supermarkets is not a primary structural determinant of obesity among low-income women. This finding is critical because many of the policy initiatives focused around 'food deserts' are based on the perception that supermarket availability is a primary structural constraint in both metropolitan and rural areas [6-8].

The finding that the availability of any type of food store within a 1-mile radius of residence was associated with an increased risk of obesity in micropolitan areas highlights the critical role that urban influence may play in moderating the effect of store availability on obesity. Micropolitan areas (counties with an urban cluster between 10,000-50,000 residents) in the Midwest are growing rapidly [9], and have unique economic, social, and demographic characteristics that may foster the creation of obesogenic environments. These characteristics include suburbanization, rapid increases in ethnic minority populations, lack of public transportation infrastructure and reliance on the automobile, and sprawl associated with being regional commercial centers. Although most research on food environments and obesity have focused on metropolitan areas, these results suggest that future research should investigate the association between built environments and obesity within micropolitan areas. Micropolitan areas with large, recently immigrated Hispanic communities (like several counties included in our Kansas study) also provide a unique opportunity to explore the role of food environments in the dietary acculturation process associated with greater risk of obesity with longer residence in the U.S.

The finding that rural residence was associated with a 21% increase in obesity risk among WIC mothers, independent of individual level covariates, also highlights the importance of investigating factors contributing to obesity risk across the urban-rural continuum. Although the presence of supermarkets or grocery stores was not associated with any change in obesity risk within the stratified rural sample, the increased risk of obesity within the rural WIC population suggests that there are other factors within the physical, economic, or social environment that may contribute to increased obesity. Future research should focus on identifying components, and elucidating causal pathways to provide greater understanding of obesity risks in rural areas, particularly among low-income women and other vulnerable groups.

Chapter Four builds on previous chapters by utilizing multi-level modeling techniques to identify the contextual effects associated with tract deprivation, tract supermarket availability, and body mass index (BMI) within the WIC participants in Kansas. Deprivation index factor scores, utilizing 7 census tract socioeconomic variables extracted from the U.S. Census, were derived for each census tract within Kansas. Deprivation index factor scores provide a multidimensional measure of tract socioeconomic status, and high tract or neighborhood deprivation index values have been associated with a wide range of negative health outcomes [10-13]. The deprivation-amplification hypothesis, as described by Macintyre and colleagues [14, 15] suggests that residence in a high deprivation tract amplifies the effects of individual level risk factors, and contributes to the relatively consistent finding that area deprivation is associated with poor health outcomes independent of individual level covariates.

Based on previous research linking tract deprivation to poor health outcomes, the first hypothesis tested in Chapter Four was that high levels of tract deprivation would be associated with higher BMI among WIC participants. This relationship was observed within our metropolitan WIC population, and we observed a similar (but not significant) trend within our rural WIC population. However, the association between tract deprivation and BMI was not linear within our micropolitan WIC population, and both high and low deprivation tracts had lower BMI as compared to intermediate deprivation tracts. This result, in conjunction with the results obtained on the association between store availability and obesity in micropolitan areas, provides further evidence of the need to investigate the potentially unique characteristics of micropolitan environments.

As might be expected given the results obtained in Chapters Two and Three, supermarket and grocery store availability did not mediate the association between tract deprivation and BMI among WIC populations across the urban-rural continuum. Taken in conjunction with the results from the other chapters, these results provide further support for the hypothesis that lack of supermarkets is not likely to be a significant structural barrier associated with the development of eating patterns associated with obesity.

The impetus to conduct this research was based in this author's longstanding involvement in issues associated with community food security organizations, which have done a great service to bring to light the inequities in our food system that may contribute to increased health risks in vulnerable populations. The elevation of structural disparities associated with supermarket availability as a public health issue has gained substantial ground in recent years, including a provision in the 2008 US Farm Bill to provide funding for research on areas that lack access to supermarkets (a.k.a. food deserts.) However, as recently highlighted by Cummins [8, 16] and Macintyre[14], much of the discourse surrounding food desert debates is based on untested assumptions regarding resource availability in deprived areas, and structurally deterministic models that simplify the complex and recursive relationships between individuals and their environment.

The results reported in this dissertation suggest that the lack of availability to supermarkets is not likely a structural determinant of obesity within low-income populations in Kansas. However, these results should not be construed to mean that food environments don't matter or aren't important factors in the development of or disparities in obesity. Rather, these results emphasize the importance of developing richer conceptual models that better depict the complex relationships between food environments and obesity, and identifying specific hypotheses that can be tested to elucidate these causal pathways. Future research should integrate longitudinal studies, as well as qualitative research, and these studies should be conducted across the urban-rural continuum. Lastly, these studies should be accompanied by controlled intervention trials that specifically explore shopping and dietary changes associated with changes in the food environment.

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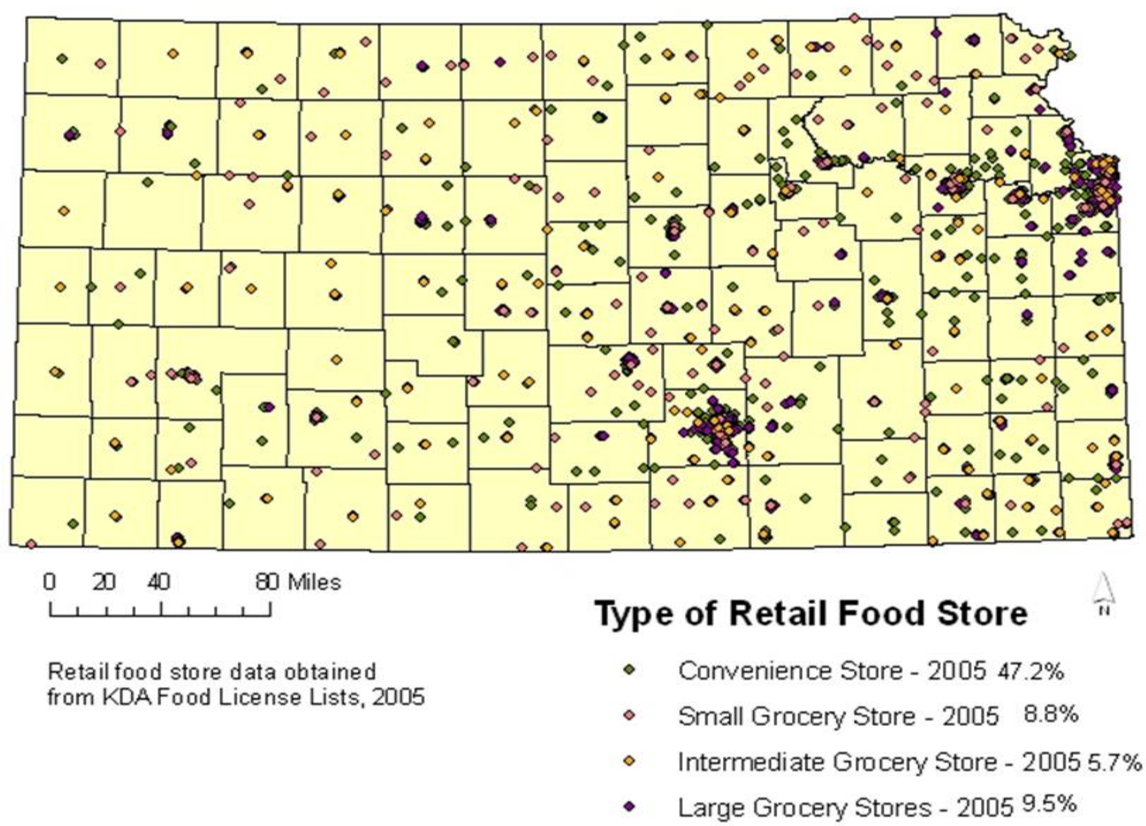
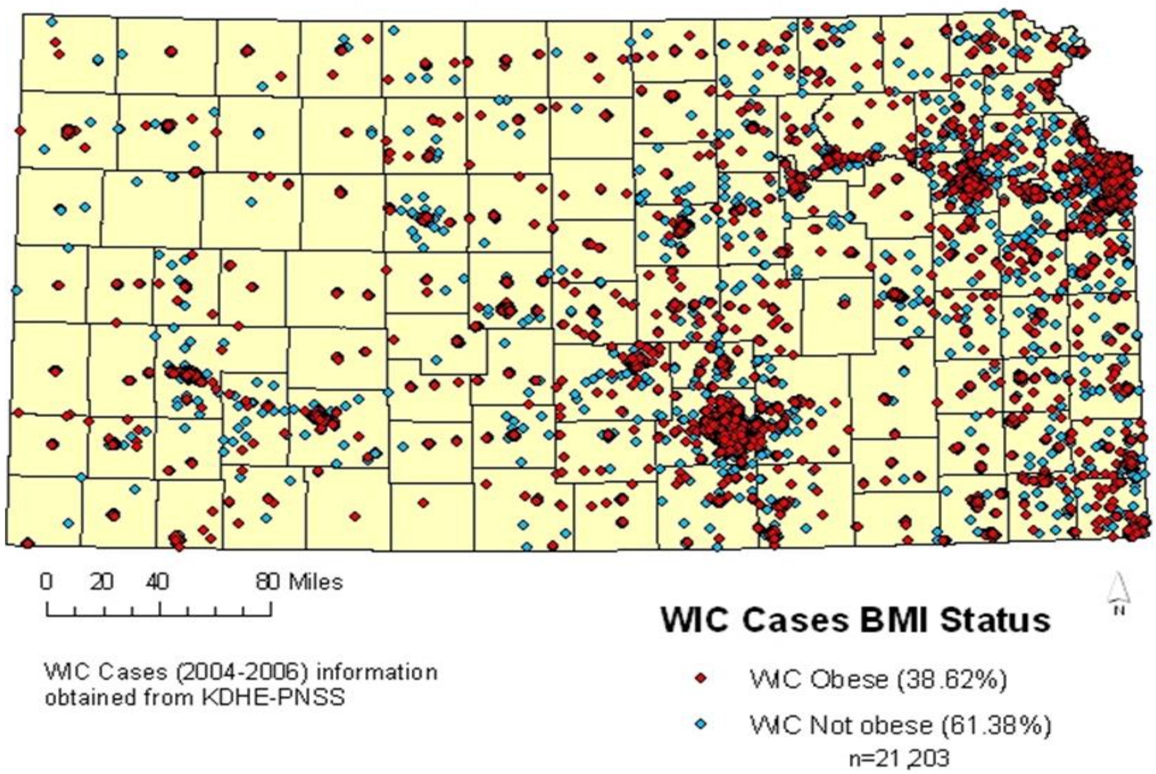
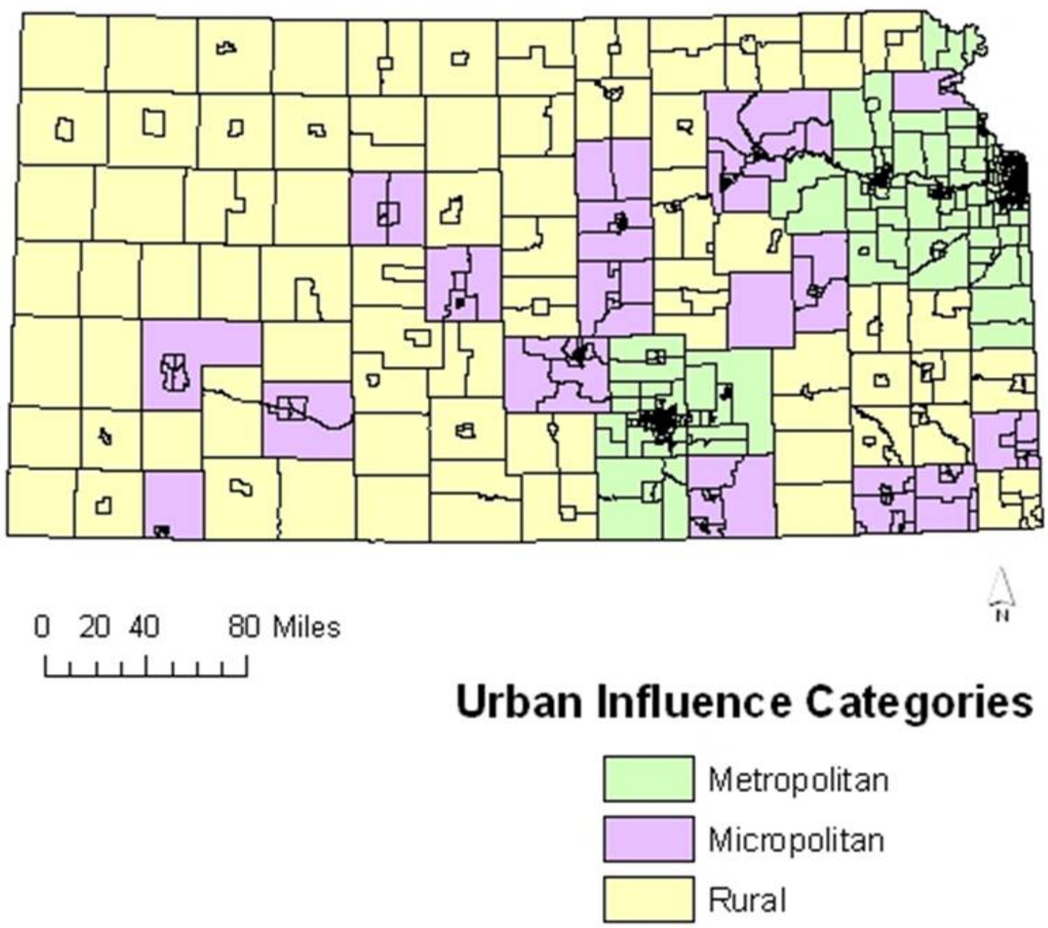
Retail food stores available in Kansas, 2005



Women participating in the Special Supplemental Nutrition Program for Women, Infants, and Children in Kansas (9/2004-12/2006)



Urban influence category of counties in Kansas



Countiesacross the urban-rural continuum in Kansas

Metropolitan	Micropolitan	Rural	
Butler	Atchison	Allen	Ness
Doniphan	Barton	Anderson	Norton
Douglas	Chase	Barber	Osborne
Franklin	Cowley	Bourbon	Pawnee
Harvey	Crawford	Brown	Phillips
Jackson	Ellis	Chautauqua	Pratt
Jefferson	Finney	Cherokee	Rawlins
Johnson	Ford	Cheyenne	Republic
Leavenworth	Geary	Clark	Rice
Linn	Labette	Clay	Rooks
Miami	Lyon	Cloud	Rush
Osage	McPherson	Coffey	Russell
Sedgwick	Montgomery	Comanche	Scott
Shawnee	Ottawa	Decatur	Sheridan
Sumner	Pottawatomie	Dickinson	Sherman
Wabaunsee	Reno	Edwards	Smith
Wyandotte	Riley	Elk	Stafford
	Saline	Ellsworth	Stanton
	Seward	Gove	Stevens
		Graham	Thomas
		Grant	Trego
		Gray	Wallace
		Greeley	Washington
		Greenwood	Wichita
		Hamilton	Wilson
		Harper	Woodson
		Haskell	
		Hodgeman	
		Jewell	
		Kearny	
		Kingman	
		Kiowa	
		Lane	
		Lincoln	
		Logan	
		Marion	
		Marshall	
		Meade	
		Mitchell	
		Morris	
		Morton	
		Nemaha	
		Neosho	