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Leaving the food desert: An activity space approach to understanding how community food environments affect health

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Abstract

Leaving the food desert: An activity space approach to understanding how community food environments affect health
By Ilana G. Raskind

Unequal access to healthy, affordable foods is hypothesized to be a key underlying cause of race- and class-based disparities in diet- and weight-related health in the United States. However, evidence for the specific pathways through which food environments affect health is inconclusive. Mixed findings may result from several methodological challenges, including: a reliance on residential neighborhood-based measures of exposure, a lack of data on actual food shopping practices, and limited attention to differences within underserved communities.

The present study uses an activity space approach, defined by the full extent of locations people routinely visit, to evaluate: 1) whether measures of food access, and their association with food shopping practices, differ by the use of residential neighborhood versus activity space measurement approaches, 2) whether associations between food access and dietary intake or body mass index (BMI) differ by the use of residential neighborhood versus activity space measurement approaches, 3) whether food shopping practices are associated with dietary intake or BMI, and 4) whether food access or food shopping practices differ by food security status.

We recruited African American women between the ages of 18-44 (n=199) from two safety-net health care clinics in Atlanta, Georgia. Activity space data were collected using an adapted version of the Visualization and Evaluation of Routine Itineraries, Travel destinations, and Activity Spaces (VERITAS) tool. We obtained retail food outlet data from the Georgia Departments of Public Health and Agriculture, and assessed three dimensions of food access: density, proximity, and quality. We measured dietary intake using a food frequency questionnaire and abstracted BMI from medical records. We used generalized estimating equations (GEE) to estimate adjusted associations between exposures and outcomes, controlling for the correlation of women within residential census tracts.

Food access differed between the residential neighborhood and activity space environments across all three dimensions of access. However, associations between food access and food shopping practices, dietary intake, and BMI did not differ by environment type. Food access in the residential neighborhood *and* the activity space was associated with food shopping practices and BMI, while food shopping practices were associated with dietary intake. Importantly, the most salient dimensions of access varied by outlet type. Finally, we found limited evidence that food access or food shopping practices varied by food security status.

While activity space approaches more precisely represent the environments to which people are exposed, they do not offer a magic bullet for understanding the complex pathways through which food environments affect health. Continued examination of exposure *and* use, acknowledgement of the multidimensionality of access, and attention to the unique food environments women experience as they move through their daily lives, will provide much needed insight into how food environments can be modified to be more supportive of healthy eating.

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Chapter 1: Introduction

Introduction

Healthy dietary behaviors and the maintenance of healthy body weight can dramatically decrease risk for numerous non-communicable diseases (NCDs), including cardiovascular disease, type 2 diabetes mellitus, and various types of cancer.[1-3] In the United States (U.S.), suboptimal dietary intake and obesity are highly prevalent, and there are substantial disparities by race, socioeconomic status (SES), and gender. Diet quality is persistently lower among non-Hispanic blacks and people with lower levels of income and education, and recent data indicate that socioeconomic disparities have, in fact, worsened over time.[4] Meanwhile, obesity continues to affect nearly 40% of U.S. adults and shows few signs of improvement; levels remain particularly high among non-Hispanic black women, over half of whom were obese in 2015-2016.[5]

Against the backdrop of poor diet quality, epidemic obesity, and the limited impact of individual-level interventions, the role of the community food environment in promoting unhealthy eating and weight gain has been the target of much inquiry in recent decades.[6-8] There is extensive evidence that socioeconomically disadvantaged and predominantly minority neighborhoods in the U.S. have poorer access to healthier food sources, such as supermarkets, and greater access to less healthy food sources, such as fast food outlets.[9-13] As such, the community food environment offers a compelling explanation for substantial race- and SES-based disparities in diet- and weight-related health. However, while existing research has provided some evidence of positive associations between supermarket availability and diet quality,[14] inverse associations between supermarket availability and obesity,[15] and positive associations between fast food availability and obesity,[15] the majority of existing results are null.[14,16]

While it is possible that the community food environment has less of an influence on diet- and weight-related health than is theorized, prior mixed findings may also result from several key methodological challenges currently facing food environment research. First, conventional measurement approaches rely on administratively-defined residential neighborhoods to delineate the environments to which people are exposed. In reality, people are 'spatially polygamous',[17] moving through a variety of places in their daily lives: going to work, visiting friends and family, shopping, and more. As a result, using residential neighborhood boundaries to define exposure may substantially misclassify individual experiences of the food environment. Second, food environment research frequently lacks data on how people *interact* with their food environments, including where, when, and how they acquire food. Without data on actual food shopping practices, researchers must assume that the food outlets to which people are exposed accurately represent the food outlets they use. However, food environments, particularly in urban areas, typically contain a multiplicity of options, both healthy and unhealthy, and it is unlikely that people use all of the outlets to which they are exposed.[18-20]

To address these limitations, food environment researchers have begun to integrate the concept of 'activity spaces' into their work.[21-23] Activity space approaches seek to measure the totality of places people visit on a routine basis in order to provide a more comprehensive representation of the food environments to which people are exposed, and capture actual food shopping practices. A small, but growing, body of literature has demonstrated how using an activity space approach may offer additional insight into the pathways through which food environments affect health. Overall, these studies have found that activity spaces are substantially larger than residential neighborhoods, and contain a higher number and density of food outlets.[21-23] Fewer studies have examined associations with diet- and weight-related health, and among those that have, results are mixed. Some studies have identified associations between food environments and dietary intake in activity spaces, but not residential neighborhoods,[21,24] some have observed associations between food environments and BMI in residential neighborhoods, but not activity spaces,[25] and still others have found no association between food environments and BMI in either residential neighborhoods or activity spaces.[26] There is an urgent need for research to clarify differences between residential neighborhood and activity space measures of the food environment and their effect on health.

An additional limitation of existing food environment research is a lack of attention to differences *within* low-income and predominantly minority communities that may affect food outlet exposure and use.

In particular, the experience of food insecurity—"a household-level economic and social condition of limited or uncertain access to adequate food"[27]—has received little attention in relation to the food environment, despite its association with numerous diet- and weight-related health conditions, including poor diet quality, obesity, hypertension, and diabetes.[28,29] Although food insecurity is commonly understood as a purely economic condition of limited financial resources, the reality is more complex. In 2017, nearly two-thirds of households living below the federal poverty line did not experience food insecurity,[27] raising important questions regarding the role of other risk factors. While individual- and interpersonal-level risk factors for food insecurity are well-documented, few studies have attempted to put food security "into place" by examining associations with features of the broader environments in which people live, work, and play.[30,31] The ways in which the food environment may exacerbate or mitigate food insecurity are likely complex, and research is urgently needed to untangle these relationships.

Specific aims, conceptual framework, and gaps addressed

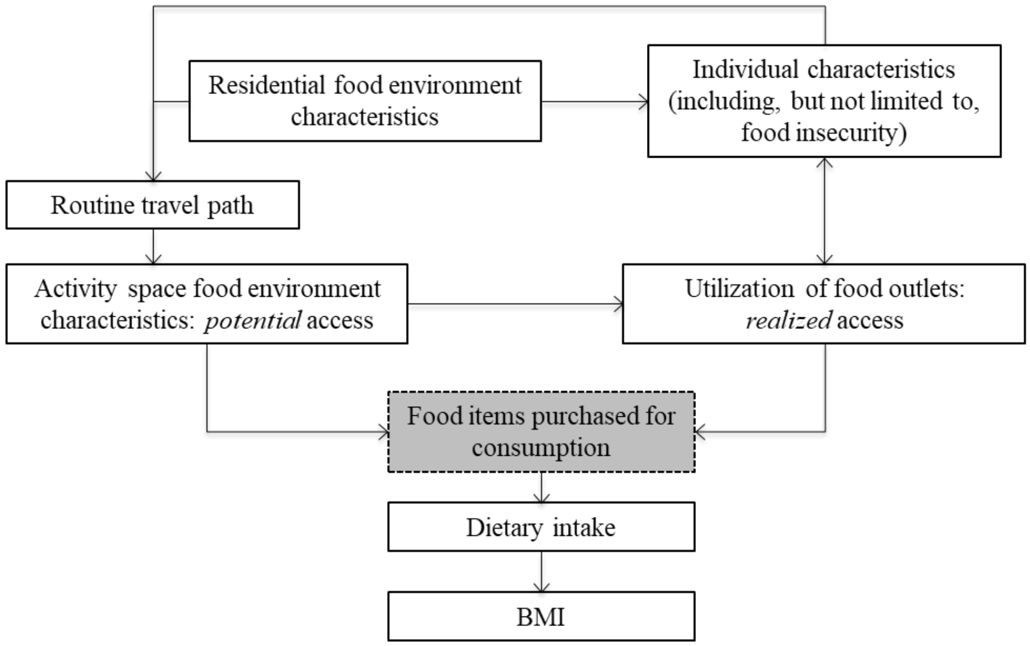
This dissertation is guided by a relational approach to food environment research.[77] This approach seeks to "reconnect people and place"[77] by moving away from conceptualizing the food environment as a singular and static entity that uniformly affects diet- and weight-related decision-making, toward a dynamic understanding of how individual and environmental characteristics interact to influence choice. Specifically, we use an activity space approach to address the following aims:

- Aim 1: Evaluate whether features of the food environment differ by the use of residential neighborhood versus activity space measures among of low-income African American women ages 18-44 recruited from two safety-net health care clinics in Atlanta, GA.
    - Aim 1a: Assess whether features of the food environment are associated with actual food shopping practices, and whether associations differ by the use of residential neighborhood versus activity space measures.
- Aim 2: Examine 1) whether associations between features of the food environment and dietary

intake or body mass index (BMI) differ by the use of residential neighborhood versus activity space measures, and 2) whether food purchasing practices are associated with dietary intake or BMI.

- Aim 3: Explore whether there are differences by food security status in 1) features of the food environment in the residential neighborhood and activity space, and 2) food shopping practices.

Figure 1 provides additional detail on the proposed pathways through which individual and environmental characteristics may interact to influence diet- and weight-related health. A woman's individual characteristics, including, but not limited to, the experience of food insecurity, as well as features of her residential food environment (e.g. whether there is a supermarket located near her home), affect her routine travel path—or the locations she regularly visits. These locations ultimately determine the food outlets to which she is routinely exposed, which together comprise her activity space food environment. However, exposure is not equal to utilization. Numerous factors affect the decision to use a particular food outlet, such as affordability, cleanliness, safety concerns, the availability of culturally relevant foods, family friendliness, and more.[32-34] The same food outlet may be "accessible" to one person and "inaccessible" to another. The degree of alignment between food outlet characteristics and individual needs, priorities, and preferences will ultimately determine use, and subsequent effects on dietary intake and BMI.



Note. Adapted from Zenk et al. 2014 and Sharkey et al. 2010. Gray boxes represent variables not explicitly measured.

Figure 1. Conceptual model of pathways through which individual and environmental characteristics may interact to influence diet- and weight-related health

The present study seeks to advance understanding of the pathways through community food environments affect health by addressing four key research gaps. First, despite increasing calls to integrate activity space approaches into food environment research, the evidence base describing differences between residential neighborhood and activity space measures of the food environment is small. Further, existing studies have primarily focused on differences in food *availability*, such as the count or density of food outlets present in a given area. In this study, we examine two additional dimensions of food access including geographic proximity and quality. We also examine a diverse set of food outlet types, including supermarkets, grocery stores, convenience stores, discount stores, limited service outlets, and full service restaurants. The majority of existing research has evaluated a much smaller set of outlet types, limiting our ability to understand the food environment as a cohesive landscape.

Second, our study builds on, and extends, the even smaller body of literature examining how associations between features of the food environment and health vary by residential neighborhood versus activity space measurement approaches. Building this evidence base is critical to understanding whether prior inconclusive findings regarding the pathways through which food environments affect health do, in fact, result from a reliance on residential neighborhood environments to delineate exposure. Again, we explore this question through an examination of multiple dimensions of food access across multiple types of food outlets.

Third, we examine actual food shopping practices and their association with dietary intake and BMI. Despite recognition that the food outlets to which people are exposed likely do not accurately represent the food outlets they use, the majority of existing studies have been limited by a lack of data on where, when, and how people acquire food. With data on food outlet exposure *and* use, we are able to explore two questions which have received limited attention in the food environment literature: 1) how do features of the food environments to which women are exposed affect their food shopping practices, and 2) do associations between features of the food environments to which women are exposed and dietary intake/BMI differ from associations between food shopping practices and dietary intake/BMI. Examining food access and actual food shopping practices may offer additional insights into how people and places interact to affect health.

Finally, we examine a potentially important source of variation among individuals within low-income communities—the experience of food insecurity—that may be related to food source exposure and use. Food insecurity has received very little attention from food environment researchers despite its direct relevance to diet- and weight-related health. Understanding whether food secure and food insecure women are exposed to different food environments, and whether food shopping practices differ by food security status, may shed light on factors beyond the individual-level that help explain why some low-income families are food insecure while others are not. Such information is also useful in determining whether interventions seeking to improve food environments and food shopping practices, which typically treat undeserved communities as uniform populations, may require special tailoring by food security status.

Our study has important implications for practice. Despite largely inconclusive evidence for how food environments affect health, efforts to improve food environments in underserved areas have proliferated: federal funding programs have been developed to incentivize the opening of new supermarkets, local zoning regulations have sought to restrict the establishment of new fast food outlets, and community-based farmers' markets and gardens have opened across the U.S. Further, despite the investment of considerable resources, evidence for the effectiveness of these interventions is limited. Better aligning our methodological approaches with our conceptual understanding of the complex ways in which people interact with their environments may help advance our understanding of the mechanisms through which food environments affect health, information critical to the development of effective interventions.

The remainder of this chapter provides a more in-depth review of the evidence for the pathways through which community food environments affect health, race- and class-based disparities in the community food environment, the use of activity space approaches in food environment research, and existing research on community food environments and food insecurity. After reviewing the literature, we present our findings for each aim in chapters two, three, and four, respectively, and then conclude with an overall summary of findings, strengths and limitations, and implications for research and practice.

Literature review

Community food environments and health. Characteristics of community food environments have received increasing attention as key correlates of diet- and weight-related health.[6-8] The community food environment is best understood as one component of a much larger set of environmental influences on what people eat. Glanz et al.[6] outline three key types of food environments, which work together to affect individual eating patterns: the community food environment, the organizational food environment, and the consumer food environment. The *community food environment*, which is the sole focus of the current study, is defined as the number, type, and location of food retailers within a community. Existing evidence supports the presence of negative associations between supermarket availability and obesity, and positive associations between fast food availability and obesity[15,35] However, despite these trends, several reviews have emphasized that the majority of existing results are, in fact, null; important methodological limitations, to which a majority of studies are subject, restrict ability to draw substantive conclusions.[15,36-38]

Unlike the community food environment, the *organizational food environment* is comprised of various food sources to which an individual may be exposed that are *not* open to the general public, including home, workplace, school, and religious institutions. The *consumer food environment* describes the foods available within each community and organizational setting, including quality, placement, price, method of promotion, and nutritional information presented to the consumer. In addition to these three environment types, there are myriad other potential influences on individual dietary behavior operating at various levels of the social ecology, such as cultural norms, media and advertising, agricultural policy, social support, and individual preferences [7]. While the complexity of human behavior requires recognition of all possible influences, the Glanz et al.[6] conceptual model provides a basic framework within which to consider the tangible environments most individuals are exposed to on a daily basis.

The multidimensionality of food access. When assessing how features of the community food environment may affect health it is necessary to define and operationalize "food access". Although food access is a multidimensional construct, studies of the community food environment that employ geographic information system (GIS)-based methods almost exclusively measure *availability* (number, diversity, and density of food retailers present in an area), and *accessibility* (e.g. distance or travel time from residence to food retailer) of food resources.[39,40] However, many other factors may influence a woman's decision to use the resources to which she is exposed. In a systematic review assessing associations between the community food environment and diet, Caspi et al. outline three dimensions of access, in addition to availability and accessibility, that may affect where a person chooses to shop, including *affordability* (e.g. the price of various food items, available discounts and sales),[34,39,41] *acceptability* (e.g. cleanliness of store, cultural acceptability of foods offered),[39,42] and *accommodation* (e.g. flexible store hours, acceptance of food assistance benefits).[39] In addition, how a woman *perceives* her food environment may also have bearing on the resources she decides to use. A recent longitudinal study found that higher perceived accessibility of fruits and vegetables was associated with a decrease in BMI over time, whereas the association between observed accessibility and BMI was null.[43] The authors suggest that perceived measures may tap into additional dimensions of accessibility that are not captured through objective measurement.[43]

Nationally representative data on household grocery shopping patterns support the notion that the availability or accessibility of a store will not necessarily translate to its use.[44] On average, the primary store used for grocery shopping was nearly four miles away from home despite the fact that the nearest supermarket was approximately two miles away. It is notable that this finding held across strata of SES given class-based disparities in transportation options—95% of higher income households used their own vehicle for shopping trips compared to only 68% of lower income households.[44] Mixed evidence for the public health impact of introducing new food retailers into underserved communities has complicated the assumption that "if you build it, they will come", and has led to greater interest in understanding the reasons why people choose to bypass stores closer to home.[33,45] Recent research that has attempted to situate grocery shopping within routine travel patterns may provide important insight: data from the American Time Use Survey indicate that only 64% of trips to the grocery store were from home to the store and back, while the rest were clustered with other activities and travel to and from home and work.[44]

Activity space approaches provide the opportunity to assess how food shopping is situated within broader patterns of mobility, and to examine how this spatial behavior is related to features of the environment in which it occurs. However, like GIS-based methods, activity space approaches cannot answer the question of *why* a particular resource has been chosen over another. As a result, researchers have underscored the importance of using complementary qualitative methods as a tool for enriching spatial data.[33,46-48] Two recent studies used complementary geospatial and qualitative methods to examine decision-making within local food environments. Both studies found that participants frequently traveled beyond their neighborhood of residence or closest supermarket to purchase groceries, and regularly shopped at multiple stores.[33,45] Qualitative interviews conducted with residents of two low-income Minneapolis neighborhoods identified three contextual domains that affected choice of shopping location: features of the neighborhoods (e.g. whether stores were located in a safe neighborhood); features of the stores themselves (e.g. quality of food, treatment by store employees); and features of the transportation system (e.g. proximity of stores to bus stops).[45] In a socio-economically diverse sample of Black women living in Philadelphia, convenience was the primary driver of store choice.[33] Convenience was discussed in regard to the store's proximity to home or other routine locations, like childcare settings; location in an area where there were multiple stores to shop at; and features of the store itself, like a clear layout and child-friendly amenities. Across both studies, when choosing where to shop, participants sought to balance various priorities and concerns within an existing set of environmental constraints. A limited number of other studies have examined how features of the *social* environment may affect the use of food resources, such as safety concerns, preference to shop with other customers of a similar race or SES, and the avoidance of discrimination or poor treatment.[32,42,49]

Individual food shopping practices as a mediator of the association between community food environments and health. Individual food shopping practices are a key conceptual mediator of the association between features of the community food environment and health. However, prior research has largely focused on how food shopping practices affect diet- and weight-related health, without examining how features of the food environment may have shaped these practices in the first place. Previous research has found that shopping at specialty grocery stores,[40,50] farmers' markets,[40] or supermarkets,[50] and shopping more frequently,[51] are associated with higher intake of fruits and vegetables, while shopping at low-cost supermarkets is associated with lower fruit and vegetable consumption.[52] Others have observed that traveling a longer distance to the supermarket[53] and primarily shopping at a supercenter or warehouse club store[54] are associated with a higher BMI, while more frequent use of fast food outlets is associated with poorer diet quality. However, some studies have found no association between BMI and the type of store used,[55] distance traveled,[56] or shopping frequency.[57]

Few studies have examined how features of the food environment may affect food shopping practices. Among primary food shoppers in South Carolina, Liese et al.[51] found that a greater number of supermarkets available within the residential neighborhood was associated with a shorter distance traveled to the utilized primary food store and a greater number of shopping trips. With regard to the quality of the food environment, Cannuscio et al.[58] found that urban residents in Philadelphia were more likely to shop closer to home if their nearby supermarkets offered healthier and more diverse food items. Also in Philadelphia, Hillier et al.[59] found that distance to the nearest chain supermarket was positively associated with the distance traveled for shopping. Other studies have found no associations between features of the food environment, including food outlet density[60] and distance to the nearest outlet,[57,60] and various food shopping practices. Research on how food environments influence food shopping practices is even more limited in the activity space literature. In one notable exception, Widener et al.[61] found that exposure to a higher number of limited-service restaurants in the activity space was associated with a lower number of grocery store trips, and a higher number of restaurant trips. How associations between the food environment and food shopping practices differ between residential neighborhood and activity space measurement approaches has yet to be examined.

Race- and class-based disparities in the community food environment. There is extensive evidence that more socioeconomically disadvantaged and predominantly black neighborhoods in the U.S. have poorer access to healthier food sources, such as supermarkets, and greater access to less healthy food sources, such as fast food chains.[9-13,62-67] Several studies have explored the propensity of fast food chains to locate within predominantly black urban neighborhoods,[11] and of supermarkets to disinvest from urban black neighborhoods or locate in predominantly white neighborhoods, a practice referred to as 'supermarket redlining'.[68-70] The vast majority of food environment studies have found both race and class to be potent predictors of exposure to less healthy food environments, yet fewer have attempted to disentangle their respective contributions.[65,71,72]

Previous research examining food environments at the intersection of race and class has found that socio-economic status alone does not account for observed disparities. In a national sample, Bower et al. found that, at all levels of poverty, predominantly black census tracts had fewer supermarkets than predominantly white, predominantly Hispanic, and integrated census tracts.[71] In addition to observed racial disparities, there was an inverse association between census tract poverty level and the number of supermarkets present, which the authors describe as a "double jeopardy" faced by census tracts that are both poor and predominantly black.[71] In New York City, in census block groups (CBGs) stratified by median income, fast food density was positively associated with percent of the CBG that was black, yet negatively associated with percent white in both low and medium income CBGs. The associations were not significant in CBGs with a high median income. Importantly, when the authors looked exclusively at predominantly black CBGs, median household income was not associated with fast food density; in other words, exposure to fast food restaurants was similar in all predominantly black CBGs regardless of area income.[65] In metropolitan Detroit, Zenk et al. found that in high poverty census tracts, distance to the nearest supermarket was farther in predominantly black tracts than in predominantly white tracts. However, these racial disparities were not observed in low poverty census tracts.[72] While the above studies provide ample evidence that disparities in food environments cannot be fully explained by class, the precise relationships between race and class and how they may vary across settings, are not fully understood.

Importantly, the disparities we observe today are the result of specific historical processes that have shaped the food environments of low-income urban communities of color. By the mid-20th century, small, independent grocery stores were no longer the primary source of food in communities across the U.S. Between 1950 and 1960, chain supermarkets came to dominate the retail food market, increasing from 35% to 70% of the market share.[68] However, as poor racial and ethnic minorities became increasingly concentrated in high-poverty neighborhoods throughout the 1970s and 1980s, supermarket chains began to disinvest from urban areas, closing existing stores and declining to open new ones. Industry representatives defended the choice to relocate to suburban areas citing higher operating costs, lower profit margins, and increasing problems of theft in urban areas.[68] Meanwhile, as supermarket chains left, fast food outlets were moving into poor urban neighborhoods. Following the race-related riots of the 1960s, the federal government sought to spur urban revitalization by providing loans to small businesses and minority entrepreneurs who would operate in minority neighborhoods. These loans were largely taken advantage of by fast food companies whose franchises qualified as small businesses, and who were seeking a new market after saturation in suburban areas.[73] The poor retail environments in many urban black neighborhoods were attractive to fast food companies who were able to benefit from low rent, little competition, and abundant low wage labor.

Activity space approaches in food environment research. The use of activity space approaches in food environment research has increased in response to two key methodological limitations facing current approaches to defining and measuring the food environment: the modifiable areal unit problem (MAUP) and the uncertain geographic context problem (UGCoP). First, the MAUP demonstrates how the researcher's choice of neighborhood scale and boundary can affect study results.[47,74-77] The majority of existing food environment research has used administrative units, such as census tracts, to assess the impact of the local food environment on diet- and weight-related outcomes.[78] However, few studies have explicitly assessed the presence of 'scale effects', or how associations between the exposure and outcome may vary if a different administrative unit, at a larger or smaller scale, was chosen.[76,79] To illustrate this issue Fan et al. used four different geographic scales (census tract, census block group, ZIP code, and 1 km buffer) to examine the association between the food environment and individual obesity risk in Salt Lake City, finding that the significance of the associations varied depending on the scale used and the type of food outlet considered (e.g. fast food restaurant or convenience store).[79] In addition to the use of varying administrative units and other researcher-defined boundaries, the use of resident-defined, or perceived neighborhood boundaries, may reveal similar effects.[80]

Second, the UGCoP challenges the assumption that the residential neighborhood is the only salient environment in which to measure exposure.[81,82] Indeed, several studies have found that people frequently conduct the majority of their food shopping outside of their neighborhood environments.[53,59,83] This suggests that existing research, which largely relies on the residential neighborhood as a proxy for the food environment, may not adequately capture the food environments to which people are exposed as they move through their daily lives.[82] In addition to recognizing the importance of human mobility, the UGCoP also emphasizes the temporal dimension of environmental exposure and access. The environments to which we are exposed may depend upon the amount of time we have available to engage in certain activities, and contextual effects may differ depending upon the length of time we spend in the places we visit.[81,84] Widener and Shannon highlight the importance of integrating time into food environment research, discussing various temporal factors that may affect food accessibility, such as the hours a food outlet is open, the time available for food shopping, the way in which food environments change over time through processes like gentrification, and the cyclical nature of food assistance benefits, which can result in more or less money available for food at different points each month.[85]

These methodological limitations have led to increased interest in the use of ‘activity space’ or ‘routine-based’ measures of exposure in food environment research, which explicitly acknowledge that individuals routinely move through a variety of spaces in their daily lives.[17,22,23,86-88] Notable findings from these studies include: 1) activity space environments are larger and contain a greater diversity of food resources than neighborhood environments,[22,23,88] 2) activity space food environments may be associated with health outcomes when residential food environments are not,[88] and 3) associations between health outcomes and varying definitions of the food environment may be modified by individual characteristics, such as gender.[87] For example, in a Canadian sample, Kestens et al. found that activity space food environments were more consistently and strongly associated with overweight than residential food environments for men, whereas residential food environments were more strongly associated with overweight for women.[87] In a sample of adults living in Detroit, higher density of fast food restaurants in activity spaces was associated with higher saturated fat intake and lower whole grain intake, while fast food density in the residential environment was not associated with any dietary behaviors.[88] These results demonstrate that using an activity space approach to measure exposure to the food environment may produce a richer and more accurate picture of the food resources to which people are exposed.

Community food environments and food insecurity. In 2017, 11.8% of U.S. households experienced food insecurity, which is defined by the U.S. Department of Agriculture as "a household-level economic and social condition of limited or uncertain access to adequate food".[27] As it is measured in the U.S., the experience of food insecurity can range in severity from diminished diet quality, variety, or desirability to disrupted eating patterns and actual reductions in food intake. Food insecurity has been associated with numerous diet- and weight-related health conditions, including poor diet quality, obesity, hypertension, dyslipidemia, and diabetes.[28,29] Importantly, significant socio-demographic disparities exist: low-income households, non-Hispanic black and Hispanic households, households with children, and households headed by a single parent, particularly mothers, have a substantially higher prevalence of food insecurity compared to the national average.[27] However, while food insecurity and poverty are closely related, they are not synonymous. In 2017, nearly two-thirds of households living below the federal poverty line did not experience food insecurity,[27] raising important questions regarding the role of other risk factors.

Prior research seeking to explain the antecedents and consequences of food insecurity has primarily focused on individual- and interpersonal-level factors. Living with a disability,[89] substance use,[90] limited social support,[91,92] and experiencing intimate partner violence[93] or adverse childhood experiences[94] have been associated with a greater likelihood of experiencing food insecurity. Few studies have examined factors at higher levels of the social ecology. A systematic review of research on place characteristics and food insecurity found that living location on the urban-rural continuum was the most commonly examined feature of the environment.[30] Findings indicated a potential protective effect of living in rural areas. Other research has found that more favorable state-level economic and policy environments (e.g. accessibility of the Supplemental Nutrition Assistance Program (SNAP) and school meal programs, and generosity of the Earned Income Tax Credit (EITC)) are associated with better food security-related outcomes.[31]

Despite its relevance to diet- and weight-related health, food insecurity has received little attention in relation to the food environment. A limited number of studies have examined how perceived and objective food access are associated with food security status. Regarding perceived access, adults in Philadelphia who reported better access to fruits and vegetables were less likely to be food insecure,[95] food insecure families in South Carolina had lower odds of good perceived access to healthy and affordable foods,[96] and low-income African American families in Baltimore who perceived healthy foods to be affordable and convenient had lower odds of experiencing food insecurity.[97] However, among low-income families in Toronto, there was no association between perceived food access or objective proximity to supermarkets and food security status.[98] The association between supermarket proximity and food security status was also null among families in South Carolina.[96] Among households with elementary school children in Wisconsin, very low proximity to supermarkets and grocery stores (i.e. ≥ 15 miles) was associated with higher odds of food insecurity.[99]

A smaller number of studies have examined how food insecure households utilize their food environments. Traveling a farther distance to the store where most groceries were purchased was associated with higher odds of adult food insecurity among Mexican-origin families along the Texas-Mexico border,[100] while the types of outlets where families purchased food was not associated with food security status among low-income African American families in Baltimore.[97] Food insecure families in South Carolina had higher odds of reporting a convenience or dollar store as the store where they shop most often, and traveled fewer total miles to shop.[101] Although a recent study by Kaiser et al. identified numerous differences in the food shopping behaviors of food secure and food insecure households, analyses were not adjusted for potential confounding variables.[102] Given the socioeconomic diversity of the sample, observed differences may be attributable to differences in the food shopping practices of high- and low-income households.

Although not contextualized in the broader food environments within which they occur, prior research has documented numerous food-related coping strategies food insecure families use to mitigate food insufficiency. Such strategies include relying on social support systems to borrow food, using charitable food sources, such as food pantries, soup kitchens, and shelters, visiting stores that offer free samples, buying in bulk or purchasing inexpensive, damaged, or expired foods, shoplifting food, and acquiring discarded food.[103,104] While some of these strategies may be protective against food insecurity, others may pose health, safety, or legal risks.[103] Importantly, evidence indicates that these strategies are unique responses to the experience of food insecurity, and that they are not used by all individuals or households with limited financial resources. Within low-income populations, using a greater number of coping strategies, and using them more frequently, has been associated with higher levels of food insecurity.[105,106] Additional research is needed to situate these coping strategies, and other food shopping practices, in the community food environments within which they occur. A greater understanding of how food insecure families utilize their food environments, and recognition of how they differ from other low-income families, may help improve the effectiveness of interventions designed to make the food environment more supportive of healthy eating.

Conclusion

The present study builds upon the literature reviewed above by addressing four key research gaps: 1) despite increasing calls to integrate activity space approaches into food environment research, the evidence base describing differences between residential neighborhood and activity space measures of the food environment is small, 2) an even smaller body of literature has examined how associations between features of the food environment and health vary by residential neighborhood versus activity space measurement approaches; building this evidence base is critical to understanding whether prior inconclusive findings regarding the pathways through which food environments affect health do, in fact, result from a reliance on residential neighborhood environments to delineate exposure, 3) despite recognition that the food outlets to which people are exposed likely do not accurately represent the food outlets they use, the majority of existing studies have been limited by a lack of data on where, when, and how people acquire food; examining food access and actual food shopping practices may offer additional insights into how people and places interact to affect health, and 4) food insecurity has received very little attention from food environment researchers despite its direct relevance to diet- and weight-related health. Understanding whether food secure and food insecure women are exposed to different food environments, and whether food shopping practices differ by food security status, may shed light on factors beyond the individual-level that help explain why some low-income families are food insecure while others are not.

To address these gaps and advance understanding of the pathways through community food environments affect health, we use an activity space approach to examine the following aims:

- Aim 1: Evaluate whether features of the food environment differ by the use of residential neighborhood versus activity space measures among of low-income African American women ages 18-44 recruited from two safety-net health care clinics in Atlanta, GA.
    - Aim 1a: Assess whether features of the food environment are associated with actual food shopping practices, and whether associations differ by the use of residential neighborhood versus activity space measures.
- Aim 2: Examine 1) whether associations between features of the food environment and dietary intake/body mass index (BMI) differ by the use of residential neighborhood versus activity space measures, and 2) whether food purchasing practices are associated with dietary intake/BMI.
- Aim 3: Explore whether there are differences by food security status in 1) features of the food environment in the residential neighborhood and activity space, and 2) food shopping practices.

References

1. Sotos-Prieto M, Bhupathiraju SN, Mattei J, et al. Changes in Diet Quality Scores and Risk of Cardiovascular Disease Among US Men and Women. *Circulation.* 2015;132(23):2212-2219.

2. Benjamin EJ, Blaha MJ, Chiuve SE, et al. Heart Disease and Stroke Statistics—2017 Update: A Report From the American Heart Association. *Circulation.* 2017.

3. Mozaffarian D. Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. *Circulation.* 2016;133(2):187-225.

4. Rehm CD, Peñalvo JL, Afshin A, Mozaffarian D. Dietary intake among us adults, 1999-2012. *JAMA.* 2016;315(23):2542-2553.

5. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in Obesity Among Adults in the United States, 2005 to 2014. *JAMA.* 2016;315(21):2284-2291.

6. Glanz K, Sallis JF, Saelens BE, Frank LD. Healthy Nutrition Environments: Concepts and Measures. *American Journal of Health Promotion.* 2005;19(5):330-333.

7. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: policy and environmental approaches. *Annu Rev Public Health.* 2008;29:253-272.

8. Sallis JF, Glanz K. Physical activity and food environments: solutions to the obesity epidemic. *Milbank Q.* 2009;87(1):123-154.

9. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med.* 2009;36(1):74-81.

10. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built Environments and Obesity in Disadvantaged Populations. *Epidemiologic Reviews.* 2009;31(1):7-20.

11. Kwate NOA. Fried chicken and fresh apples: Racial segregation as a fundamental cause of fast food density in black neighborhoods. *Health & Place.* 2008;14(1):32-44.

12. Black C, Moon G, Baird J. Dietary inequalities: What is the evidence for the effect of the neighbourhood food environment? *Health & Place.* 2014;27:229-242.

13. Powell LM, Slater S, Mirtcheva D, Bao Y, Chaloupka FJ. Food store availability and neighborhood characteristics in the United States. *Preventive Medicine.* 2007;44(3):189-195.

14. Bivoltsis A, Cervigni E, Trapp G, Knuiman M, Hooper P, Ambrosini GL. Food environments and dietary intakes among adults: does the type of spatial exposure measurement matter? A systematic review. *International Journal of Health Geographics.* 2018;17(1):19.

15. Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CAM. The relationship of the local food environment with obesity: A systematic review of methods, study quality, and results. *Obesity.* 2015;23(7):1331-1344.

16. Wilkins E, Radley D, Morris M, et al. A systematic review employing the GeoFERN framework to examine methods, reporting quality and associations between the retail food environment and obesity. *Health & Place.* 2019;57:186-199.

17. Matthews SA, Yang T-C. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist.* 2013.

18. Clary C, Matthews SA, Kestens Y. Between exposure, access and use: Reconsidering foodscape influences on dietary behaviours. *Health & Place.* 2017;44:1-7.

19. Brown DR, Brewster LG. The food environment is a complex social network. *Social Science & Medicine.* 2015;133:202-204.

20. Cooksey-Stowers K, Schwartz MB, Brownell KD. Food Swamps Predict Obesity Rates Better Than Food Deserts in the United States. *International Journal of Environmental Research and Public Health.* 2017;14(11):1366.

21. Zenk SN, Schulz AJ, Matthews SA. Activity space environment and eating and physical activity behaviors: A pilot study. *Health and Place.* 2011;17:1150 - 1161.

22. Kestens Y, Lebel A, Daniel M, Thériault M, Pampalon R. Using experienced activity spaces to measure foodscape exposure. *Health & Place.* 2010;16(6):1094-1103.

23. Crawford TW, Jilcott Pitts SB, McGuirt JT, Keyserling TC, Ammerman AS. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health & Place.* 2014;30:215-225.

24. Shearer C, Rainham D, Blanchard C, Dummer T, Lyons R, Kirk S. Measuring food availability and accessibility among adolescents: Moving beyond the neighbourhood boundary. *Social Science & Medicine.* 2015;133:322-330.

25. Tamura K, Elbel B, Athens JK, et al. Assessments of residential and global positioning system activity space for food environments, body mass index and blood pressure among low-income housing residents in New York City. *Geospatial health.* 2018;13(2).

26. Burgoine T, Jones AP, Namenek Brouwer RJ, Benjamin Neelon SE. Associations between BMI and home, school and route environmental exposures estimated using GPS and GIS: do we see evidence of selective daily mobility bias in children? *International Journal of Health Geographics.* 2015;14(1):8.

27. Coleman-Jensen A, Rabbitt M, Gregory C, Singh A. *Household Food Security in the United States in 2017.* United States Department of Agriculture;2018.

28. Laraia BA. Food insecurity and chronic disease. *Advances in nutrition (Bethesda, Md).* 2013;4(2):203-212.

29. Gundersen C, Ziliak JP. Food Insecurity And Health Outcomes. *Health Aff (Millwood).* 2015;34(11):1830-1839.

30. Carter MA, Dubois L, Tremblay MS. Place and food insecurity: a critical review and synthesis of the literature. *Public Health Nutrition.* 2014;17(01):94-112.

31. Bartfeld J, Men F. Food Insecurity among Households with Children: The Role of the State Economic and Policy Context. *Social Service Review.* 2017;91(4):691-732.

32. Cannuscio CC, Hillier A, Karpyn A, Glanz K. The social dynamics of healthy food shopping and store choice in an urban environment. *Social Science & Medicine.* 2014;122:13-20.

33. DiSantis KI, Hillier A, Holaday R, Kumanyika S. Why do you shop there? A mixed methods study mapping household food shopping patterns onto weekly routines of black women. *The international journal of behavioral nutrition and physical activity.* 2016;13(1):11.

34. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and Supermarket Access: Proximity or Price? *American journal of public health.* 2012;102(8):e74-e80.

35. Yan R, Bastian ND, Griffin PM. Association of food environment and food retailers with obesity in US adults. *Health & Place.* 2015;33:19-24.

36. Black JL, Macinko J. Neighborhoods and obesity. *Nutr Rev.* 2008;66(1):2-20.

37. Feng J, Glass TA, Curriero FC, Stewart WF, Schwartz BS. The built environment and obesity: A systematic review of the epidemiologic evidence. *Health & Place.* 2010;16(2):175-190.

38. Lucan SC. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *J Acad Nutr Diet.* 2015;115(2):205-212.

39. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. *Health & place.* 2012;18(5):1172-1187.

40. Gustafson A, Christian JW, Lewis S, Moore K, Jilcott S. Food venue choice, consumer food environment, but not food venue availability within daily travel patterns are associated with dietary intake among adults, Lexington Kentucky 2011. *Nutrition Journal.* 2013;12(1):1-11.

41. Ghosh-Dastidar B, Cohen D, Hunter G, et al. Distance to Store, Food Prices, and Obesity in Urban Food Deserts. *American journal of preventive medicine.* 2014;47(5):587-595.

42. Zenk SN, Odoms-Young AM, Dallas C, et al. "You have to hunt for the fruits, the vegetables": environmental barriers and adaptive strategies to acquire food in a low-income African American neighborhood. *Health Educ Behav.* 2011;38(3):282-292.

43. Zenk SN, Mentz G, Schulz AJ, Johnson-Lawrence V, Gaines CR. Longitudinal Associations Between Observed and Perceived Neighborhood Food Availability and Body Mass Index in a Multiethnic Urban Sample. *Health Education & Behavior.* 2016.

44. Ver Ploeg M, Mancino L, Todd JE, Clay DM, Scharadin B. *Where Do Americans Usually Shop for Food and How Do They Travel To Get There? Initial Findings From the National Household Food Acquisition and Purchase Survey.* United States Department of Agriculture, Economic Research Service;2015.

45. Shannon J. Beyond the Supermarket Solution: Linking Food Deserts, Neighborhood Context, and Everyday Mobility. *Annals of the American Association of Geographers.* 2016;106(1):186-202.

46. Franco M, Bilal U, Diez-Roux AV. Preventing non-communicable diseases through structural changes in urban environments. *Journal of Epidemiology and Community Health.* 2015;69(6):509-511.

47. Diez Roux AV. Investigating Neighborhood and Area Effects on Health. *Am J Public Health.* 2001;91(11):1783-1789.

48. Matthews SA, Detwiler JE, Burton LM. Geo-ethnography: Coupling Geographic Information Analysis Techniques with Ethnographic Methods in Urban Research. *Cartographica: The International Journal for Geographic Information and Geovisualization.* 2005;40(4):75-90.

49. Zenk SN, Schulz AJ, Israel BA, et al. Food shopping behaviours and exposure to discrimination. *Public Health Nutr.* 2014;17(5):1167-1176.

50. Zenk SN, Schulz AJ, Hollis-Neely T, et al. Fruit and Vegetable Intake in African Americans: Income and Store Characteristics. *American Journal of Preventive Medicine.* 2005;29(1):1-9.

51. Liese AD, Bell BA, Barnes TL, et al. Environmental influences on fruit and vegetable intake: results from a path analytic model. *Public Health Nutrition.* 2014;17(11):2595-2604.

52. Aggarwal A, Cook AJ, Jiao J, et al. Access to Supermarkets and Fruit and Vegetable Consumption. *American journal of public health.* 2014;104(5):917-923.

53. Inagami S, Cohen DA, Finch BK, Asch SM. You Are Where You Shop: Grocery Store Locations, Weight, and Neighborhoods. *American Journal of Preventive Medicine.* 2006;31(1):10-17.

54. Liese AD, Ma XN, Hutto B, Sharpe PA, Bell BA, Wilcox S. Food Shopping and Acquisition Behaviors in Relation to BMI among Residents of Low-Income Communities in South Carolina. *International Journal of Environmental Research and Public Health.* 2017;14(9):1075.

55. Jilcott Pitts SB, McGuirt JT, Carr LJ, Wu Q, Keyserling TC. Associations between Body Mass Index, Shopping Behaviors, Amenity Density, and Characteristics of the Neighborhood Food Environment among Female Adult Supplemental Nutrition Assistance Program (SNAP) Participants in Eastern North Carolina. *Ecology of Food and Nutrition.* 2012;51(6):526-541.

56. Lear SA, Gasevic D, Schuurman N. Association of supermarket characteristics with the body mass index of their shoppers. *Nutrition Journal.* 2013;12(1):117.

57. Dubowitz T, Zenk SN, Ghosh-Dastidar B, et al. Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutr.* 2015;18(12):2220-2230.

58. Cannuscio CC, Tappe K, Hillier A, Buttenheim A, Karpyn A, Glanz K. Urban Food Environments and Residents' Shopping Behaviors. *American Journal of Preventive Medicine.* 2013;45(5):606-614.

59. Hillier A, Cannuscio CC, Karpyn A, McLaughlin J, Chilton M, Glanz K. How Far Do Low-Income Parents Travel to Shop for Food? Empirical Evidence from Two Urban Neighborhoods. *Urban Geography.* 2011;32(5):712-729.

60. Laska MN, Hearst MO, Forsyth A, Pasch KE, Lytle L. Neighbourhood food environments: are they associated with adolescent dietary intake, food purchases and weight status? *Public Health Nutrition.* 2010;13(11):1757-1763.

61. Widener MJ, Minaker LM, Reid JL, Patterson Z, Ahmadi TK, Hammond D. Activity space-based measures of the food environment and their relationships to food purchasing behaviours for young urban adults in Canada. *Public Health Nutrition.* 2018;21(11):2103-2116.

62. Morland K, Wing S, Diez Roux A, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. *American Journal of Preventive Medicine.* 2002;22(1):23-29.

63. Powell LM, Chaloupka FJ, Bao Y. The Availability of Fast-Food and Full-Service Restaurants in the United States: Associations with Neighborhood Characteristics. *American Journal of Preventive Medicine.* 2007;33(4, Supplement):S240-S245.

64. Ford PB, Dzewaltowski DA. Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses. *Nutr Rev.* 2008;66(4):216-228.

65. Kwate NOA, Yau C-Y, Loh J-M, Williams D. Inequality in obesigenic environments: Fast food density in New York City. *Health & Place.* 2009;15(1):364-373.

66. Walker RE, Keane CR, Burke JG. Disparities and access to healthy food in the United States: A review of food deserts literature. *Health & Place.* 2010;16(5):876-884.

67. James P, Arcaya MC, Parker DM, Tucker-Seeley RD, Subramanian SV. Do minority and poor neighborhoods have higher access to fast-food restaurants in the United States? *Health & Place.* 2014;29:10-17.

68. Eisenhauer E. In poor health: Supermarket redlining and urban nutrition. *GeoJournal.* 2001;53(2):125-133.

69. Zhang M, Ghosh D. Spatial Supermarket Redlining and Neighborhood Vulnerability: A Case Study of Hartford, Connecticut. *Transactions in GIS.* 2016;20(1):79-100.

70. Chen H-J, Wang Y. The changing food outlet distributions and local contextual factors in the United States. *BMC Public Health.* 2014;14(1):1-11.

71. Bower KM, Thorpe Jr RJ, Rohde C, Gaskin DJ. The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Prev Med.* 2014;58:33-39.

72. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML. Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. *American journal of public health.* 2005;95(4):660-667.

73. Jou C. *Supersizing Urban America: How Inner Cities Got Fast Food with Government Help.* University of Chicago Press; 2017.

74. Openshaw S. The modifiable areal unit problem. In. Vol 38. Norwich, England: Geobooks; 1983.

75. Flowerdew R, Manley DJ, Sabel CE. Neighbourhood effects on health: does it matter where you draw the boundaries? *Soc Sci Med.* 2008;66(6):1241-1255.

76. Barnes TL, Colabianchi N, Hibbert JD, Porter DE, Lawson AB, Liese AD. Scale effects in food environment research: Implications from assessing socioeconomic dimensions of supermarket accessibility in an eight-county region of South Carolina. *Applied Geography.* 2016;68:20-27.

77. Cummins S, Curtis S, Diez-Roux AV, Macintyre S. Understanding and representing 'place' in health research: a relational approach. *Soc Sci Med.* 2007;65(9):1825-1838.

78. Charreire H, Casey R, Salze P, et al. Measuring the food environment using geographical information systems: A methodological review. *Public Health Nutrition.* 2010;13(11):1773-1785.

79. Fan JX, Hanson HA, Zick CD, Brown BB, Kowaleski-Jones L, Smith KR. Geographic scale matters in detecting the relationship between neighbourhood food environments and obesity risk: an analysis of driver license records in Salt Lake County, Utah. *BMJ Open.* 2014;4(8):e005458.

80. Chaix B, Merlo J, Evans D, Leal C, Havard S. Neighbourhoods in eco-epidemiologic research: Delimiting personal exposure areas. A response to Riva, Gauvin, Apparicio and Brodeur. *Social Science & Medicine.* 2009;69(9):1306-1310.

81. Kwan M-P. The Uncertain Geographic Context Problem. *Annals of the Association of American Geographers.* 2012;102(5):958-968.

82. Chen X, Kwan M-P. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. *American journal of public health.* 2015;105(9):1734-1737.

83. Liu JL, Han B, Cohen DA. Beyond Neighborhood Food Environments: Distance Traveled to Food Establishments in 5 US Cities, 2009-2011. *Preventing chronic disease.* 2015;12:E126.

84. Kwan M-P. Beyond Space (As We Knew It): Toward Temporally Integrated Geographies of Segregation, Health, and Accessibility. *Annals of the Association of American Geographers.* 2013;103(5):1078-1086.

85. Widener MJ, Shannon J. When are food deserts? Integrating time into research on food accessibility. *Health & Place.* 2014;30:1-3.

86. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine.* 2012;43(4):440-450.

87. Kestens Y, Lebel A, Chaix B, et al. Association between Activity Space Exposure to Food Establishments and Individual Risk of Overweight. *PLoS ONE.* 2012;7(8):e41418.

88. Zenk SN, Schulz AJ, Matthews SA, et al. Activity space environment and dietary and physical activity behaviors: A pilot study. *Health & Place.* 2011;17(5):1150-1161.

89. Coleman-Jensen A, Nord M. Food insecurity among households with working-age adults with disabilities. *USDA-ERS Economic Research Report.* 2013(144).

90. Gundersen C, Ziliak JP. Childhood Food Insecurity in the U.S.: Trends, Causes, and Policy Options. *The Future of Children.* 2014:1-19.

91. Walker JL, Holben DH, Kropf ML, Holcomb JP, Anderson H. Household food insecurity is inversely associated with social capital and health in females from Special Supplemental Nutrition Program for Women, Infants, and Children Households in Appalachian Ohio. *Journal of the American Dietetic Association.* 2007;107(11):1998-1993.

92. Dean WR, Sharkey JR. Food insecurity, social capital and perceived personal disparity in a predominantly rural region of Texas: An individual-level analysis. *Social Science & Medicine.* 2011;72:1454-1462.

93. Hernandez DC, Marshall A, Mineo C. Maternal Depression Mediates the Association Between Intimate Partner Violence and Food Insecurity. *Journal of Women's Health.* 2013;23(1):29-37.

94. Sun J, Knowles M, Patel F, Frank DA, Heeren TC, Chilton M. Childhood Adversity and Adult Reports of Food Insecurity Among Households With Children. *Am J Prev Med.* 2016;50(5):561-572.

95. Mayer VL, Hillier A, Bachhuber MA, Long JA. Food Insecurity, Neighborhood Food Access, and Food Assistance in Philadelphia. *J Urban Health.* 2014;91(6):1087-1097.

96. Ma X, Liese AD, Bell BA, et al. Perceived and geographic food access and food security status among households with children. *Public Health Nutrition.* 2016;19(15):2781-2788.

97. Vedovato GM, Surkan PJ, Jones-Smith J, et al. Food insecurity, overweight and obesity among low-income African-American families in Baltimore City: associations with food-related perceptions. *Public Health Nutr.* 2016;19(8):1405-1416.

98. Kirkpatrick SI, Tarasuk V. Assessing the relevance of neighbourhood characteristics to the household food security of low-income Toronto families. *Public Health Nutrition.* 2010;13(7):1139-1148.

99. Bartfeld JS, Ryu J-H, Wang L. Local Characteristics Are Linked to Food Insecurity Among Households With Elementary School Children. *Journal of Hunger & Environmental Nutrition.* 2010;5(4):471-483.

100. Sharkey JR, Dean WR, Johnson CM. Association of household and community characteristics with adult and child food insecurity among Mexican-origin households in colonias along the Texas-Mexico border. *Int J Equity Health.* 2011;10.

101. Ma X, Liese AD, Hibbert J, Bell BA, Wilcox S, Sharpe PA. The Association between Food Security and Store-Specific and Overall Food Shopping Behaviors. *Journal of the Academy of Nutrition and Dietetics.* 2017;117(12):1931-1940.

102. Kaiser ML, Carr JK, Fontanella S. A tale of two food environments: Differences in food availability and food shopping behaviors between food insecure and food secure households. *Journal of Hunger & Environmental Nutrition.* 2019;14(3):297-317.

103. Kempson K, Keenan DP, Sadani PS, Adler A. Maintaining food sufficiency: Coping strategies identified by limited-resource individuals versus nutrition educators. *Journal of nutrition education and behavior.* 2003;35(4):179-188.

104. Anater AS, McWilliams R, Latkin CA. Food acquisition practices used by food-insecure individuals when they are concerned about having sufficient food for themselves and their households. *Journal of Hunger & Environmental Nutrition.* 2011;6:27-44.

105. Wood DK, Shultz JA, Edlefsen M, Butkus SN. Food coping strategies used by food pantry clients at different levels of household food security status. *Journal of Hunger & Environmental Nutrition.* 2006;1(3):45-68.

106. Pinard C, Smith TM, Calloway EE, Fricke HE, Bertmann FM, Yaroch AL. Auxiliary measures to assess factors related to food insecurity: Preliminary testing and baseline characteristics of newly designed hunger-coping scales. *Preventive Medicine Reports.* 2016;4:289-295.

Chapter 2: Crossing imaginary lines: An activity space approach to understanding how food environments affect the food shopping practices of low-income African American mothers in Atlanta, GA

Abstract

Background: Inconclusive evidence for how food environments affect health may result from a host of methodological challenges in the design and analysis of food environment research, including a reliance on neighborhood-based measures of exposure, a lack of data on the retailers where people actually purchase food, and inattention to how features of the food environment may affect food shopping practices.

Objective: We use an activity space approach, defined by the full extent of locations people routinely visit, to assess associations between food access and food shopping practices, and compare whether these associations differ by the use of residential neighborhood or activity space measures.

Methods: African American women between the ages of 18-44 (n=199) were recruited from two safety-net health care clinics in Atlanta, Georgia. We collected activity space data using an adapted version of the VERITAS questionnaire. We obtained retail food outlet data from the Georgia Departments of Health and Agriculture. We assessed three dimensions of food access: availability, geographic proximity, and quality. We used GEE to estimate adjusted associations between food access and food shopping practices.

Results: Food access differed between residential neighborhood and activity space environments across all three dimensions. However, associations between food access and food shopping practices were consistent across definitions of the environment, although the magnitude of associations varied. How women interacted with their food environments varied considerably by food outlet type. Geographic proximity was associated with limited service outlet purchasing practices, while availability was associated with supermarket shopping practices.

Conclusions: Future research should seek to understand when and how differences between residential and activity space environments may affect associations between food access and diet-related health behaviors and outcomes, with attention to differences by food outlet type.

Introduction

Unequal access to healthy, affordable foods is hypothesized to be a key underlying cause of race- and class-based disparities in diet- and weight-related health in the United States.[1-3] As a result, efforts to improve food environments in underserved areas have proliferated: federal funding programs have been developed to incentivize the opening of new supermarkets,[4] local zoning regulations have sought to restrict the establishment of new fast food outlets,[5] and community-based farmers' markets and gardens have opened across the U.S.[6] However, despite the investment of considerable resources, evidence for how food environments affect health is inconclusive. While some studies have observed positive associations between supermarket availability and diet quality,[2] negative associations between supermarket availability and obesity,[7] and positive associations between fast food availability and obesity,[7] a substantial proportion of findings are null.[7-9]

Although it is possible that food environments have less of an influence on diet- and weight-related health than is theorized, it is also possible that prior mixed findings result from a host of methodological challenges in the design and analysis of food environment research, including: a reliance on residential neighborhoods to define and measure exposure, despite the fact that people move through a variety of places in their daily lives; a lack of data on where people actually purchase food, requiring researchers to implicitly assume that exposure is equal to utilization; and inattention to how features of the food environment may affect food shopping practices, an important conceptual mediator of the relationship between food environments and health. As individuals move through their daily lives, they construct the boundaries of their unique food environments within which food-related decision-making occurs. Better aligning our methodological approaches with our conceptual understanding of the complex ways in which people interact with their environments may help explain prior inconclusive findings and advance our understanding of the mechanisms through which food environments affect health.

Residential neighborhoods, commonly operationalized using administrative boundaries like census tracts, are often used to delineate the food environments to which people are exposed.[10] However, people likely visit numerous places in the course of a day, such as work, school, errands, social activities, and more, and are rarely confined to the often arbitrary boundaries of their residential neighborhoods.[11] To address this limitation, food environment researchers have begun to integrate the concept of 'activity spaces', or the full collection of locations a person visits on a routine basis, into their work.[12-14] Measuring individual activity spaces may provide a more accurate representation of the food environments to which people are exposed, and help elucidate the pathways through which these environments affect health. Several studies have compared how features of the food environment differ between residential neighborhood and activity space measurement approaches. Overall, these studies have found that activity spaces are substantially larger than residential neighborhoods,[12,15] and contain a greater number and density of food outlets.[12,13,15] Still, additional research is needed to understand the differences between residential neighborhood and activity space measures of food access and whether these differences impact the estimation of health effects.

Food environment research is also limited by a lack of data on where people actually purchase food. Most studies of the neighborhood food environment implicitly assume that people purchase food in their residential areas, and, by extension, that proximity to food retailers is a key determinant of use. However, it is unlikely that outlets available in the residential neighborhood accurately represent the outlets people use: food is commonly purchased outside of the residential neighborhood[16-19] and numerous factors beyond geographic proximity affect the decision to use a particular food outlet, such as affordability,[18,20,21] accessibility via public transportation,[22] cleanliness,[23] safety concerns,[23] and the availability of culturally relevant foods.[24] Further, the relative importance of such factors likely varies by individual characteristics, priorities, and preferences.[25] By collecting data on where people actually purchase food, activity space approaches provide researchers with the opportunity to examine how people navigate and interact with their food environments, rather than treating the food environment as a static entity that affects all people in the same way.

Individual food shopping and procurement practices are a key conceptual mediator of the association between the food environment and diet-related health.[26-28] However, despite increasing interest in how people interact with their food environments, prior research has largely focused on how food shopping and procurement practices affect diet-related health, without examining how features of the food environment may have shaped these practices in the first place. Previous research has found that shopping at specialty grocery stores,[29,30] farmers' markets,[29] or supermarkets[30] as well as shopping more frequently[26] are associated with higher fruit and vegetable consumption, while shopping at low-cost supermarkets is associated with lower fruit and vegetable consumption.[31] Others have found that traveling a longer distance to the supermarket[32] and primarily shopping at a supercenter or warehouse club store[33] are associated with a higher BMI. However, some studies have found no association between BMI and the type of store used,[27] distance traveled,[34] or shopping frequency.[35]

A limited number of studies have examined how features of the food environment influence food shopping and procurement practices. In their study of primary food shoppers in South Carolina, Liese et al. found that a higher number of supermarkets available within the residential neighborhood was associated with a shorter distance traveled to the utilized primary food store and a higher number of shopping trips.[26] With regard to the quality of the food environment, Cannuscio et al. found that urban residents in Philadelphia were more likely to shop closer to home if their nearby supermarkets offered healthier and more diverse food inventories.[36] Also in Philadelphia, Hillier et al. found that distance to the nearest chain supermarket was positively associated with the distance traveled for shopping.[17] Other studies have found no associations between features of the food environment, including food outlet density[37] and distance to the nearest outlet,[35,37] and various food shopping and purchasing practices. Research on how food environments influence food shopping practices is even more limited in the activity space literature. In one notable exception, Widener et al. found that exposure to a higher number of limited-service restaurants in the activity space was associated with a lower number of grocery store trips, and a higher number of restaurant trips.[38] How associations between the food environment and food shopping practices differ between residential neighborhood and activity space measurement approaches has yet to be examined.

In the present study, we use an activity space approach to refine how 'exposure' to the food environment is defined and measured and to examine how the food environment affects food shopping practices among low-income African American mothers living in Atlanta, Georgia. First, we compare multiple definitions of the residential neighborhood and activity space food environments across three dimensions of access (availability, geographic proximity, and quality), and six types of food outlets (chain supermarkets, grocery stores, convenience stores/pharmacies, limited service outlets, and full service restaurants). We then assess whether food access is associated with food shopping practices, and whether these associations differ by the use of residential neighborhood or activity space measures of the food environment.

Methods

Population and setting. We recruited participants (n=203) from two safety-net health care clinics in Atlanta, Georgia. We approached women in the clinic waiting areas, described the study objectives, inclusion criteria, and time commitment, and asked whether they were interested in participating. Women were eligible for participation if they were African American, between the ages of 18-44, currently residing with at least one child under the age of 18, and able to comprehend written and spoken English. Women confirmed as pregnant were excluded (due to differences in nutritional requirements, dietary patterns, and weight gain, and possible activity restrictions). We chose to focus our study on low-income African American women given the disproportionate burden of diet- and weight-related disease in this population,[39,40] and the frequency with which it is targeted by related public health interventions. We further restricted our sample to women with children as they typically hold primary responsibility for household food purchasing, playing a critical role in shaping their own health as well as the health of their families.[41,42] Low-income and minority communities are often treated as uniform populations, without consideration of potential internal differences in food environment exposure and utilization. Our eligibility criteria allow us to examine differences *among* low-income African American mothers, providing potentially important insights for the targeting and tailoring of future interventions.

Study visits occurred either before or after women's appointments, depending on clinic wait times. In one clinic, visits were conducted in a private room near the patient waiting area, and in the other clinic, visits were conducted in a private corner of the waiting room. Each visit lasted approximately 45 minutes to one hour, and women were compensated $20 in cash for their time. The Emory University Institutional Review Board and the Grady Health System Research Oversight Committee approved all study procedures.

Data. ***Activity space.*** We collected activity space data using an adapted version of the Visualization and Evaluation of Routine Itineraries, Travel destinations, and Activity Spaces (VERITAS) interactive mapping tool.[43] The interviewer-administered questionnaire has embedded Google Maps functionality, which allows the interviewer to search for and identify each activity location interactively on the map. Participants identify key anchor points in their daily routine (e.g. home, work, and school), and provide the name and address of locations visited at least once in the past month. Participants were specifically prompted about 21 different types of locations, including food-seeking locations (e.g. supermarkets, restaurants), commerce or service locations (e.g. pharmacies, nail salons), social locations (e.g. movie theaters, concerts), family-related locations (e.g. family members' homes, children's schools), and health services locations (e.g. doctors, dentists). Up to five activity locations could be entered for each of the 21 location types. Contextual information, including visit frequency, visit duration, and mode of transportation, was collected for each location. The reference period for several location types (e.g. doctors, dentists, hair salons) was extended to locations visited in the past year. All questionnaires were administered face-to-face on a laptop. We defined valid locations as those falling within the Atlanta Regional Commission's (ARC) 10-county area, which includes Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry and Rockdale counties. Two recent studies evaluating the validity of VERITAS against GPS tracking found that the majority of GPS locations fell within 1,000 meters of self-reported VERITAS locations (median = 88.5% and median = 92.6%).[44,45]

***Retail food data*.** We obtained retail food outlet data from the Georgia Departments of Health (GDPH) and Agriculture (GDA) for the 10 ARC counties. Through the submission of open records requests, we obtained data on food service establishments, including fast food and full service restaurants, from GDPH's Environmental Health Inspections, and data on food retailers, including supermarkets, grocery stores, convenience stores, and discount general merchandise stores, from GDA's Food Safety Division. Food service establishment health inspections can be managed at the county- or state-level. We obtained data for eight of the 10 counties from GDPH, and data for the remaining two counties from the relevant county health departments.

We implemented a detailed protocol to clean the retail food outlet data. The protocol included four main steps: 1) geocode address data, 2) identify and remove outlets deemed ineligible for inclusion, 3) identify and remove duplicate outlets, and 4) classify outlets into categories for analysis. Appendix 1 provides additional detail on each step of the data cleaning protocol including how many retailers were excluded at each stage, the reasons for exclusion, and the GDA/GDPH categories used to classify each retailer.

In step one, we geocoded all address data using Google Maps' Geocoding API. We achieved a 99.9% match rate. Unmatched addresses resulted from extraneous data in the address field (e.g. suite numbers). We were able to remove the additional information and successfully geocode each address.

In step two, we removed outlets that were not open to the public (e.g. schools, hospitals, long-term care facilities), did not have permanent retail locations (e.g. seasonal retailers, mobile units, caterers), or were not primarily visited for the purpose of purchasing or consuming food (e.g. airports, hotels, sports arenas). We began by inspecting the existing categories used by GDA and GDPH to classify retailers and removed categories deemed ineligible based on the above criteria (e.g. "School", "Caterer", "Mobile Unit"). We then manually searched the data using a combination of key words (e.g. "hotel", "airport", "college") and hand searching to identify additional ineligible retailers.

In step three, we identified retailers with the same name located at the same latitude and longitude. Once these were removed, we manually searched retailers located at the same coordinates without an exact name match. Locations with very similar names (e.g. "Kroger" and "The Kroger Co.") were considered duplicates.

Finally, in step four, we categorized retailers into six categories for analysis: *supermarkets, grocery stores, convenience stores/pharmacies, discount general merchandise stores (e.g. dollar stores), limited service outlets (e.g. fast food outlets, coffee shops, ice cream parlors),* and *full service restaurants*. To classify supermarkets, grocery stores, convenience stores/pharmacies, and discount general merchandise stores, we primarily relied on pre-existing GDA categories included in the dataset (e.g. “Chain Store w/Seafood, Deli, Bakery, Meat Market”, “Retail / Convenience Store”). Several GDA categories that did not clearly fit within one of our six retail categories were hand searched and categorized accordingly. To classify limited service retailers and full service restaurants, we sequentially applied three strategies. First, we used a list of national limited service retailers and full service restaurants developed by Jones et al. for use in food environment research.[46] We also included three additional limited service retailers based on local knowledge (American Deli, Willy’s Mexicana Grill, Jersey Mike’s Subs). Second, for the remaining retailers, we applied existing categories used by GDPH to classify retailers (e.g. “fast food”, “full service”). If retailers could not be classified using one of the above strategies, our third strategy was to use a GDPH variable called ‘risk type’. This variable indicated whether food was cooked on the premises or whether only pre-cooked/pre-processed foods were served (e.g. ice cream, pre-cooked hot dogs that only require reheating). Retailers that fell into the latter category were classified as limited service retailers. One of the local county health department datasets did not include GDPH categories that could be used to classify each retailer. After applying the Jones et al. list of national limited service retailers and full-service restaurants, and the ‘risk type’ variable, we were only able to categorize 39% of retailers in this county. As only 1% of the activity space locations fell within this county, we removed the uncategorized retailers from the analytic dataset.

Socio-demographic data. We collected self-reported data on participant income, educational attainment, marital status, age, employment status, household size, car ownership, and receipt of Supplemental Nutrition Assistance Program (SNAP) benefits, using a web-based survey administered immediately before the activity space questionnaire.

Measures. ***Residential neighborhood and activity space environments.*** We compared food access across multiple definitions of the residential neighborhood and activity space environments. We defined the residential neighborhood in three ways: 1) the participant's residential census tract, 2) the 1-mile road network buffer surrounding the participant's home, and 3) the 2-mile road network buffer surrounding the participant's home. These definitions allow us to compare administrative environments (census tracts), which may be shared by multiple participants, with ego-centered environments (1- and 2-mile road network buffers), which are unique to each participant.[15]

We also used three definitions of the activity space environment: 1) the convex hull polygon (smallest convex polygon containing all of the participant's activity locations), 2) the collection of points representing each of the participant's activity locations, and 3) the collection of points representing each of the participant's activity locations, weighted by visit frequency and duration (hours per month). Participants reported visit frequency and duration for all locations except home. We imputed frequency and duration values for home using data from the American Time Use Survey.[47] We summed gender- and employment status-specific estimates for home-based activities (e.g. "personal care, including sleep", "household activities", "caring for and helping household members"). Unemployed and employed participants were estimated to spend 13.5 and 11.7 hours per day at home, respectively. The convex hull polygon and the collection of activity locations provide considerably different representations of the activity space environment. While convex hull polygons include the full extent of space through which people travel on a routine basis, they may contain a significant amount of space to which people are not actually exposed. In contrast, the collection of activity locations captures the environment at the precise locations people visit, but does not account for the environments to which people are exposed as they travel between locations.

Food access. We examined three dimensions of food access: availability, geographic proximity, and quality. Availability and geographic proximity were assessed separately for each of the six retailer categories. Availability was defined as the density of food outlets per square mile. We used kernel density estimation (KDE), with a 1-mile bandwidth, to create continuous exposure surfaces of food outlet density per square mile. Bandwidth selection was informed by prior food environment research.[48-50] The Centers for Disease Control and Prevention's (CDC) modified retail food environment index (mRFEI) was used to assess the quality of available outlets.[51] The mRFEI is calculated as the number of healthy food outlets in a given area divided by the number of healthy plus unhealthy food outlets in the same area. We categorized supermarkets and grocery stores as healthy food outlets, and convenience stores/pharmacies, discount general merchandise stores, and limited service retailers as unhealthy food outlets. We used KDE, with a 1-mile bandwidth, to create continuous mRFEI exposure surfaces. For the residential census tract, 1-mile road network buffer, 2-mile road network buffer, and convex hull polygon, we extracted the average density and mRFEI within each polygon. For the activity space environments, we extracted the density and mRFEI value at each activity point and calculated a raw and a time-weighted average value for each participant.

Geographic proximity was defined as the road network distance, in miles, to the nearest food outlet. We used the ArcGIS Network Analyst (Version 10.6. Redlands, California: Environmental Systems Research Institute, Inc.) to calculate road network distance. For the residential census tract, we calculated distance from the census tract centroid, for the road network buffer, we calculated distance from the participant's residence (there is no distinction between the 1- and 2-mile road network buffers for this measure), and for the activity points, we calculated the distance from each activity location to the nearest food outlet and then produced an average for each participant. There is no distance measure for the convex hull polygon.

Food shopping practices. For each food retailer category, we used the activity space data to calculate the number of unique retailers used, trip frequency, average distance from home to utilized retailers, and proportion of all retailers used within the boundaries of the residential census tract, 1-mile road network buffer, 2-mile road network buffer, and convex hull polygon, respectively. Assessing the proportion of retailers used within the boundaries of the convex hull polygon provides an indication of the degree to which women deviate from their routine travel to access food outlets. This measure assumes that outlets located within the boundaries of the routine activity space are more accessible than those located outside because they do not require deviation from routine travel.[52] The measure is calculated by constructing a convex hull polygon of all the participant's activity locations *except* locations belonging to the food retailer category in question (e.g. supermarkets, limited service retailers, etc.), and then calculating the proportion of utilized food outlets contained within the boundaries of the convex hull polygon. In addition, women reported the amount of money spent on groceries and eating out during the previous week.

Selective daily mobility bias. Selective daily mobility is a potential source of bias in activity space research, which can arise when there are unmeasured factors that affect both the places a person chooses to go and the health behaviors or outcomes of interest. Chaix et al. suggest that this form of bias may pose a particular threat when the places a person visits to engage in a specific behavior (e.g. shopping for groceries or purchasing fast food) are included in the construction of the environmental measure that is viewed as a predictor of this behavior (i.e. access to supermarkets or fast food outlets).[43] For example, if we believe that the supermarket density within a woman's activity space predicts the likelihood that she will buy her groceries at a supermarket, including the supermarkets she utilizes when measuring density may produce biased estimates of the hypothesized association. In this case, observing a positive association between supermarket density and the likelihood of buying groceries at a supermarket may be more reflective of a woman's personal motivation to shop at a supermarket than it is of how the environment affects her behavior. Excluding activity locations related to the health behavior of interest when constructing the activity space environment can minimize selective daily mobility bias. Therefore, when we assessed food access in the activity space, we excluded activity locations belonging to the retail category under examination. For example, when assessing supermarket density in the convex hull polygon, we created a convex hull polygon of all activity locations *except* utilized supermarkets before calculating density, and when assessing supermarket density at the weighted and unweighted activity space locations, we did not extract density values at the utilized supermarket locations.

Analysis. We excluded four participants due to incomplete data or data quality concerns for a final analytic sample size of 199. In addition, two participants did not disclose their residential address.

As a result, all measures and analyses based on the residential neighborhood environment reflect a sample size of 197. Finally, one participant did not report her annual income. We imputed the modal value (less than $5,000) for this participant. All data analyses were conducted in R version 3.5.1.

After constructing the residential neighborhood and activity space environments and creating summary measures of food access for each participant, we assessed differences in food availability, geographic proximity, and quality across environment types. First, we calculated the mean and standard deviation of each measure of food access, in each retail category, for each environment. To assess whether food access was significantly different across environments, we constructed 'stacked' models where measures of each environmental attribute (e.g. availability, proximity, and quality) for each of the six environment types (residential census tract, 1-mile road network buffer, 2-mile road network buffer, convex hull polygon, weighted activity space points, and unweighted activity space points) was nested within women. We used generalized estimating equations (GEE) to control for correlated measures within women and compare values of each attribute within each environment to the value of that attribute in the reference environment (the residential census tract).

Next, we assessed whether food access was associated with food shopping behaviors in each environment. While we calculated descriptive statistics of food shopping behaviors for each retailer category, we only examined associations with food access for supermarkets and limited service outlets, as they were the only outlet types used by a majority of women (n=194 and 167, respectively). The following outcome variables were Winsorized at the 95th percentile due to the presence of extreme outliers: frequency of supermarket trips, supermarket proximity, limited service proximity, amount spent on groceries, and amount spent eating out. We scaled supermarket density so that a one-unit change represents one additional supermarket per 10 square miles, and we scaled supermarket and limited service outlet proximity so that a one-unit change represents an increase of 0.25 miles. We used GEE to estimate adjusted associations between food access and food shopping behaviors controlling for the correlation of women within residential census tracts. The following food shopping behaviors were modeled as count variables: number of unique retailers used in the past month, trip frequency per month, average proximity to utilized retailers, and number of retailers used in the convex hull polygon (offset = log(total number of retailers used)).We also planned to assess the count of retailers used in the residential census tract, 1-mile road network buffer, and 2-mile road network buffer. However, almost all participants used either zero or one retailers within each of these environments. Therefore, these food shopping behaviors were modeled as binary variables; we used Poisson models with robust standard errors to estimate the relative risk of using any retailers in the given environment versus using none. We adjusted all models for the socio-demographic characteristics described above.

Results

Socio-demographic characteristics of low-income African American women in Atlanta, Georgia. By design, women ranged in age from 18 to 44, with a mean age of 32 (*SD* = 6.7) (Table 1). Approximately 14% had not completed high school, while 43% had received their high school diploma or GED, one quarter had completed some college or technical school, and the remaining 17% had obtained an Associate's degree or higher. Over half of the women were employed (37% full-time and 20% part-time), one quarter were unemployed and actively looking for work, and the remaining 19% were unemployed and not seeking employment. The majority of women had never been married (72%), and lived in households comprised, on average, of four people (*SD* = 1.6). Over one quarter of women had annual incomes less than $5,000, 16% earned between $5,000 and $9,000, and 17% earned between $10,000 and $14,999. Of the remaining 40%, the majority earned between $15,000 and $40,000 per year, while 7% earned more than $40,000. Nearly two-thirds of women owned a car (63%) and the majority received Supplemental Nutrition Assistance Program (SNAP) benefits (80%).

Comparing food access across residential neighborhood and activity space environments. All measures of food access (i.e. availability, proximity, and quality) differed between residential neighborhood and activity space definitions of the food environment (Table 2). The greatest differences were observed between the residential census tract and the unweighted activity space (i.e. activity points not weighted by frequency or duration of visit). Overall, food outlet density was higher in the activity space environments than the residential neighborhood environments. For example, compared to the residential census tract, the unweighted activity space included one additional convenience store per square mile (*M* = 3.6; *SD* = 2.6 vs. *M* = 4.6; *SD* = 1.5), and over five additional limited service outlets per square mile (*M* = 5.6; *SD* = 8.0 vs. *M* = 10.9; *SD* = 5.0). This pattern was the same across all outlet types, except discount stores for which density was similar across residential neighborhood and activity space environments.

Distance to the nearest food retailer was shorter in the activity space environments than the residential neighborhood environments. For example, the nearest supermarket was located an average of 1.8 miles (*SD* = 0.8) from the residential census tract centroid and an (unweighted) average of 1.2 miles (*SD* = 0.3) from the activity space locations, and the nearest limited service outlet was located an average of 0.8 miles (*SD* = 0.5) from the residential census tract centroid and an (unweighted) average of 0.3 miles (*SD* = 0.1) from the activity space locations. This pattern was the same across all outlet types. The mRFEI was slightly lower (i.e. less healthy) in the unweighted activity space compared to the residential census tract (*M* = 6.8, *SD* = 1.6 vs. *M* = 7.7, *SD* = 3.1).

There were no major differences in food outlet density or mRFEI across the residential neighborhood environment definitions (e.g. residential census tract, 1-mile road network buffer, and 2-mile road network buffer), however, distance to the nearest food outlet was slightly shorter from the residential address than from the census tract centroid. Because the weighted activity space environment accounted for the time each woman spent at home, the average density, proximity, and mRFEI of food outlets in the weighted activity space environment generally fell between averages for the residential neighborhood and unweighted activity space environments. Mean food outlet density and mRFEI in the convex hull polygon also typically fell between the residential neighborhood and unweighted activity space means, except discount stores for which density was slightly lower in the convex hull polygon than the residential census tract.

Food shopping practices of low-income African American mothers in Atlanta, Georgia. Nearly all women shopped at a supermarket within the past month (97%), and the majority of women purchased food at a limited service outlet (84%; the majority of which were fast food outlets). Far fewer women shopped at grocery stores (27%), convenience stores (25%), discount stores (33%), or full service restaurants (35%). Women used a median of two unique supermarkets (*IQR* = 1.3-3.0) and two unique limited service outlets (*IQR* = 1.0-2.0) in the past month, and made a median of 4.6 trips to a supermarket (*IQR* = 2.0-8.7) and 3.6 trips to a limited service outlet (*IQR* = 1.5-8.1) per month. Trip frequency was highest for convenience stores (*median* = 17.3 trips per month, *IQR* = 6.7-30.4), and lowest for full service restaurants (*median* = 1 trip per month, *IQR* = 0.3-2.0). Women travelled a median of 3.6 miles from home to supermarkets (*IQR* = 2.3-5.3), and 2.9 miles from home to limited service outlets (*IQR* = 1.7-5.1). The shortest distance was traveled to convenience stores (*median* = 0.8 miles, *IQR* = 0.3-3.7), and the longest distance was travelled to full service restaurants (*median* = 8.9 miles, *IQR* = 4.6-11.8). Women reported spending a median of $150 on groceries (*IQR* = 70.0-250.0) and $22 eating out (*IQR* = 7.0-50.0) during the previous week.

A median of zero percent of utilized food outlets fell within women's residential census tracts or 1-mile road network buffers, with the exception of convenience stores (median of 100% (*IQR* = 0.0-100.0) fell within the 1-mile road network buffer). A median of zero percent of supermarkets (*IQR* = 0.0-50.0), grocery stores (*IQR* = 0.0-100.0), and full service restaurants (*IQR* = 0.0-0.0), 100% of convenience stores (*IQR* = 0.0-100.0) and discount stores (*IQR* = 0.0-100.0), and 33.3% of limited service outlets (*IQR* = 0.0-100.0) fell within women's 2-mile road network buffers. A median of 100% of grocery stores (*IQR* = 50.0-100.0), convenience stores (*IQR* = 50.0-100.0), discount stores (*IQR* = 100.0-100.0), and limited service outlets (*IQR* = 33.3-100.0), 66.7% of supermarkets (*IQR* = 33.3-100.0), and 41.7% of full service restaurants (*IQR* = 0.0-100.0) fell within women's convex hull polygons. Considering the percentage of food outlets used within the convex hull polygon as an indicator of deviation from routine travel, women most frequently deviated from their routine activity spaces to access supermarkets and full service restaurants.

Is food outlet density associated with food shopping behaviors? Neither supermarket density nor limited service outlet density were associated with the number of unique food outlets women used or the frequency of their trips. Supermarket density was associated with the average distance women traveled from home to their utilized supermarkets. For each of the residential neighborhood environments, higher supermarket density was associated with a shorter distance traveled to the utilized supermarkets. For example, for each additional supermarket per 10 square miles in the 1-mile road network buffer, average distance to the utilized supermarkets decreased by 13% (e^{β} = 0.87, *95% CI*: 0.80-0.94). A similar association was observed for the weighted activity space environment, although the strength of the association was weaker (e^{β} = 0.92, *95% CI*: 0.86-0.99). There was no association between supermarket density in the unweighted activity space and average distance traveled. In contrast, supermarket density in the convex hull polygon was positively associated with average distance traveled: for each additional supermarket per 10 square miles in the convex hull polygon, average distance to the utilized supermarkets increased by 11% (e^{β} = 1.11, *95% CI*: 1.02-1.21). Limited service outlet density was not associated with average distance traveled to utilized limited service outlets.

Supermarket density in each residential and activity space environment, with the exception of the convex hull polygon, was positively associated with shopping at a supermarket within the residential census tract, 1-mile road network buffer, and 2-mile road network buffer. For example, for each additional supermarket per 10 square miles in the 1-mile road network buffer, women were 1.62 times as likely to shop at a supermarket within their 1-mile road network buffer (*95% CI*: 1.34-1.96). Supermarket density was not associated with the number of supermarkets women shopped at within their convex hull polygons. Limited service outlet density was not associated with purchasing food at a limited service outlet within the residential census tract, 1-mile road network buffer, or 2-mile road network buffer, or the number of limited service outlets used within the convex hull polygon.

Supermarket density in the unweighted activity space was negatively associated with the amount women spent on groceries during the previous week. For each additional supermarket per 10 square miles in the unweighted activity space, the dollar amount spent on groceries decreased by 16% (e^{β} = 0.84, *95% CI*: 0.73-0.95). Supermarket density in the other residential neighborhood and activity space environments was not associated with the amount spent on groceries during the previous week, and limited service outlet density was not associated with the amount spent eating out during the previous week.

Is food outlet proximity associated with food shopping behaviors? Distance to the nearest supermarket or limited service outlet was not associated with the number of unique food outlets women used in the past month or the frequency of their trips. Distance to the nearest limited service outlet was positively associated with the average distance traveled from home to the utilized limited service outlets. The association was strongest for distance to the nearest limited service outlet in the unweighted activity space: for each one quarter mile increase in distance to the closest limited service outlet, average distance traveled from home to the utilized limited service outlets increased by 52% (e^{β} = 1.52, *95% CI*: 1.18-1.96). Associations were similar, albeit weaker, for the tract centroid, residential address, and weighted activity space environment. Distance to the nearest supermarket was not associated with distance traveled to the utilized supermarkets (although several estimates were statistically significant, the magnitude of the associations was very small.)

Distance to the nearest supermarket in all residential neighborhood and activity space environments was negatively associated with use of a supermarket within the residential census tract, 1-mile road network buffer, and 2-mile road network buffer. For example, for each one quarter mile increase in distance from home to the nearest supermarket, women were 0.61 times as likely to use a supermarket in their 1-mile road network buffer (*95% CI*: 0.53-0.71). Although similar patterns were observed for distance to the nearest limited service outlet, associations were only significant for distance from home to the nearest limited service outlet and use of a limited service outlet within the 1-mile and 2-mile road network buffers, and distance to the nearest limited service outlet in the unweighted activity space and use of a limited service outlet within the 1-mile and 2-mile road network buffers. Distance to the nearest supermarket or limited service outlet was not associated with the number of food outlets used within the convex hull polygon, or the amount spent on groceries or eating out during the previous week.

Is the quality of the food environment associated with food shopping behaviors? There were no clear patterns or strong associations observed between the quality of the food environment, measured using the mRFEI, and any food shopping behaviors. Model results are presented in the Appendix.

Discussion

In this study, we compared the residential neighborhood and activity space food environments of low-income African American mothers living in Atlanta, Georgia, across several dimensions of food access. We assessed whether food access was associated with food shopping practices, and whether these associations differed by the use of residential neighborhood and activity space measures of the food environment. Our results indicated that residential neighborhood and activity space food environments differed across all dimensions of food access: availability, geographic proximity, and quality. However, these differences did not substantively affect our conclusions regarding how food access may affect food shopping practices. Notably, women's food shopping practices, and the associations between food access and food shopping practices, varied considerably by outlet type.

All three dimensions of food access differed between the residential neighborhood and activity space environments. Similar to previous studies, we found that residential neighborhood measures underestimated the density of food retailers to which women were routinely exposed.[13,15,53] These findings can likely be explained by conventional urban zoning ordinances that separate residential and commercial land use, resulting in higher retail density in non-residential areas. Further, we identified previously unexamined, but related, findings that women's routine activity destinations were located in closer proximity to food outlets than were their homes. Ongoing zoning reforms in Atlanta and other cities, which aim to prioritize regulation of the physical form and design of new developments, rather than strict land use requirements,[54] may affect future findings. Interestingly, the unweighted activity space environment was slightly less healthy than the residential neighborhood environment. These results are consistent with the fact that we observed smaller differences in outlet density between the residential and activity space environments for ‘healthy’ retailers (e.g. supermarkets) than for ‘unhealthy’ retailers (e.g. limited service outlets). However, our findings do not align with those of Christian, who observed healthier activity space environments among adults in Lexington, Kentucky.[53] Additional research and standardized measures of food environment quality are needed to further clarify differences between residential neighborhoods and activity spaces.

Our comparison of weighted and unweighted activity spaces raises the question of what it means to be ‘exposed’ to an environment. Our choice to weight by visit frequency and duration assumes that the longer a woman spends in a given place, the more likely it is to affect her. However, this is not necessarily true. While the home address typically carried the most weight in our analyses, a not insignificant proportion of time at home may have been spent sleeping. Is a woman ‘more exposed’ to the food environment around her home because she sleeps next to it each night? Is she ‘less exposed’ to the food environment around her child’s school where she goes every morning and afternoon, but only for five minutes? The use of weighted and unweighted activity space environments did not result in any major changes to our conclusions about how the food environment may affect food shopping practices; while the magnitude of associations varied, the direction and significance of associations was largely consistent. Several studies of the food environment have incorporated time weighting into the construction of activity space measures,[15,38,55] but differences between weighting approaches are not well understood. Decisions regarding the use of unweighted or weighted measures and various approaches to weighting will likely depend on the dimensions of access and types of food outlets in question, as well as characteristics of the study population and setting.

How women interacted with the food environment varied considerably by outlet type. Almost all women used supermarkets and limited service outlets, but only around one quarter to one third utilized grocery stores, convenience stores, discount stores, or full service restaurants. Qualitative research has indicated that low-income consumers often avoid the use of small neighborhood grocery and convenience stores as similar items can typically be found for a lower cost at larger supermarkets.[56,57] It is worth considering that popular ‘healthy corner store initiatives’ may have a more limited reach in Atlanta than in the West Coast and Northeastern cities where they were originally developed.[58] Still, for the women in our sample who did utilize convenience stores, the dietary impact may be substantial as the median number of visits per month was 17.

Recent arguments for examining activity space food environments have been supported by research indicating that the majority of grocery shopping occurs outside of the residential neighborhood.[16-19] While this was true in our sample as well, how far women traveled to purchase food varied by outlet type. Women may possess multiple mental maps of the food environment, and the relative importance of residential and non-residential areas may depend on the type of outlet intended for use. Women used convenience and discount stores close to home, likely to pick up snacks and small items needed in between trips to the supermarket. In contrast, women traveled much farther, and were most likely to deviate from their routine activity spaces, to use supermarkets and full service restaurants. Visits to these outlets are likely to be pre-planned and informed by multiple criteria, including affordability, cultural acceptability, opening hours, access from public transportation, child-friendliness, and more. Because of the number of factors involved in decision-making, supermarket and restaurant choice may be less sensitive to what is present in the neighborhood food environment, whereas more impromptu decisions regarding outlets used closer to home may be more reactive to the local environment and driven by 'whatever is around'.

In our examination of the associations between food access and shopping practices, we found further evidence that sensitivity to the food environment may vary by outlet type. While women exposed to a higher density of supermarkets, particularly in their residential environments, used supermarkets closer to home, living in closer proximity to a supermarket did not affect how close to home women shopped. Higher densities may provide women with a greater number of supermarkets to choose from, making it more likely that she will find a supermarket near home that fulfills the criteria important to her (e.g. affordability, accommodation, acceptability). Once these criteria are fulfilled, women may choose to use a supermarket closer to home. In contrast, geographic proximity on its own may not be enough to drive the decision-making process. That said, we did observe that women who lived farther from a supermarket were less likely to use a supermarket in their residential neighborhood, although this may reflect a lack of supermarkets present in the residential neighborhood to use.

The most salient dimension of access differed for limited service outlet purchasing. In contrast to supermarkets, limited service outlet density was not associated with limited service outlet purchasing practices, but women who lived in closer proximity to a limited service outlet used outlets closer to home. In comparison to supermarkets, fast food outlets are more likely to be standardized in terms of their pricing, physical appearance, and customer service, particularly within chains. Therefore, having a greater number of outlets to choose from may not impact the decision-making process as much as it does for supermarkets. As discussed above with reference to convenience stores, it may also be the case that limited service outlet purchases do not involve as much pre-planning as a trip to the supermarket.[59] Convenience is one of the most cited reasons for consuming fast food,[59,60] making it more likely that outlet choice is driven by what is present in the local environment. Further, given the abundance of limited service outlets across Atlanta, and most cities, even areas with “lower” densities are likely to have ample options available. Overall, the food environment seemed to matter more for *where* women used food outlets, than for *how* they used them. The number of unique retailers women used, the frequency with which they used them, and the amount spent while shopping, may be influenced by factors not captured in the dimensions of food access we examined, such as features of in-store environments like product pricing, availability, selection, promotion, and quality.[61]

Although features of the food environment differed between the residential neighborhood and activity space environments, the direction and significance of associations between food access and food shopping practices were generally consistent across residential and activity space measures, although the magnitude of association varied. Still, we observed some discrepancies: had we only examined the residential environment, we may have concluded that supermarket density was not associated with the amount spent on groceries, and had we only examined the activity space environment, we may have concluded that supermarket density was not clearly associated with how close to home women shopped. There are several potential explanations for our findings. It is possible that the differences we observed between the residential neighborhood and activity space environments were not meaningful in reality, and that women routinely traveled through spaces that were generally similar to their residential neighborhoods. It is well established that residential neighborhoods in the U.S. are segregated by race and class,[62,63] and this segregation may also extend to non-residential environments.[64] Further, slightly less than half of the women in our sample were unemployed and over one third did not own a car, factors which may have limited how far from home they regularly traveled and their likelihood of being exposed to environments substantively different from their residential neighborhoods.

In addition to similarities induced by broader social forces like segregation, the residential neighborhood and activity space measures are also correlated with one another by design. The residential census tracts and residential road network buffers overlap to a large extent, and the activity space necessarily includes the residential neighborhood. These correlations may help explain why food access in the activity space was associated with the likelihood of using food outlets within the residential environment. It is also possible that the residential environment plays a particularly important role in influencing health behaviors and outcomes. People typically spend a significant amount of time in their residential neighborhoods[47] where they form social ties, develop feelings of attachment and belonging, and construct shared identities.[65] Consequently, associations between food access in the activity space and food shopping practices could be driven by the residential component of the activity space. Future research could construct separate residential and non-residential environments to assess whether, and how, they independently affect health behaviors and outcomes.

Our findings also raise questions about the utility of the convex hull polygon as a representation of the activity space environment. For the most part, food access in the convex hull polygon was not associated with food shopping practices, and food access in the other environments was not associated with the likelihood of using food outlets within the convex hull polygon. Convex hull polygons, and similar measures like standard deviational ellipses, likely contain a significant amount of space to which people are not actually exposed. Consistent with our findings, Zenk et al. found that fast food outlet density in participants' daily path areas was associated with dietary intake, while density in their standard deviational ellipses was not.[12] Still, additional research is needed to clarify when and how these measures may be useful in food environment research, for example, by offering insight into the overall size, dispersion, and directionality of activity spaces.

Our study makes several important contributions to the small, but growing, body of literature seeking to move food environment research across imaginary lines and beyond the residential neighborhood. We compared multiple dimensions of food access across multiple definitions of residential neighborhood and activity space environments, including time-weighted and unweighted approaches. We also sought to account for the widely acknowledged, but irregularly addressed, issue of selective daily mobility bias. A limited number of studies have examined how features of the food environment may affect food shopping practices, and ours is one of the first to do so using an activity space approach. Still, our study is subject to several important limitations. First, activity space data were self-reported and may be subject to recall, social desirability, and other attendant biases. We attempted to minimize additional biases by using one interviewer to administer all questionnaires. The interviewer maintained detailed notes on the administration of each questionnaire, which resulted in the exclusion of four participants due to incomplete data or data quality concerns. Second, the VERITAS questionnaire asks about a subset of routine activity locations, and is not designed to capture every location the participant has visited in the past month. Participants may be routinely exposed to other environments that this study did not assess. Indeed, a recent validation study of the VERITAS questionnaire indicated that while most GPS points were located near self-reported questionnaire locations, the questionnaire-based convex hull polygon covered a small proportion of the GPS-based convex hull polygon.[45] Third, the questionnaire does not capture data on the routes participants use to travel between locations. Depending upon several factors, including mode of transportation, these paths may represent important areas of exposure. Each of the above limitations may have affected our ability to accurately characterize the environments to which women were exposed and their influence on food shopping practices. An additional limitation of our study is the use of secondary retail food outlet data. The limitations of these data are well-documented in the food environment literature (e.g. Fleischhacker et al.[66]), although in the absence of primary data, government sources are among the most accurate.[66] Further, we implemented a detailed data cleaning protocol to further improve the data quality. Finally, we have a relatively small sample that was not randomly selected, and our results are not intended to generalize to the wider population of low-income African-American mothers in Atlanta, Georgia.

Conclusions. Race- and class-based disparities in diet- and weight-related health are a significant public health problem, requiring immediate attention and innovative solutions. However, developing effective interventions requires a strong evidence base regarding the pathways through which food environments affect health. While existing interventions have primarily targeted neighborhood environments, our findings suggest that the relative importance of residential and non-residential food environments, and the most salient dimensions of access within these environments, may vary by outlet type. Future interventions may need to more fully consider the complex decision-making processes that guide outlet choice, the multidimensionality of access, and the unique food environments women create as they move through their daily lives.

Table 2.1 Characteristics of low-income African American mothers in Atlanta, GA (n = 199)

	N or Mean	% or SD
Age (*mean, SD*)	32	6.7
Education (n, %)		
Less than high school	27	13.6
HS diploma or GED	85	42.7
Some college/technical school	54	27.1
Associate's degree or higher	33	16.6
Employment status (n, %)		
Full-time	74	37.2
Part-time	39	19.6
Unemployed, seeking employment	49	24.6
Unemployed, not seeking employment	37	18.6
Marital status (n, %)		
Currently married	22	11.1
Not married, living with partner	21	10.6
Never married	143	71.9
Divorced/separated/widowed	13	6.5
Household size (*mean, SD*)	4.1	1.6
Income (annual) (n, %)		
Less than $5,000	55	27.6
$5,000-$9,999	31	15.6
$10,000-$14,999	34	17.1
$15,000-$19,999	13	6.5
$20,000-$24,999	17	8.5
$25,000-$29,000	15	7.5
$30,000-$39,999	21	10.6
Greater than $40,000	13	6.5
Car ownership (n, %)		
Yes	126	63.3
No	73	36.7
SNAP benefits (n, %)		
Yes	157	78.9
No	42	21.1

Table 2.2 Comparing food access in the residential neighborhood and activity space environments (n=199)

	Residential neighborhood [a]				**Activity space**	
	Census tract (ref) [b]	*Road network (1 mile)* [c]	*Road network (2 mile)*	*Convex hull polygon*	*Activity space points, weighted (hours/month)*	*Activity space points, unweighted*
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Supermarkets						
Density (retailers/mi^2)	0.16 (0.12)	0.17 (0.12)	0.17 (0.10)	0.22 (0.08)***	0.19 (0.12)*	0.25 (0.08)***
Proximity (distance to closest retailer) (miles)	1.81 (0.83)	1.66 (0.94)			1.60 (0.78)*	1.20 (0.29)***
Grocery stores						
Density (retailers/mi^2)	0.49 (0.35)	0.49 (0.34)	0.48 (0.31)	0.52 (0.13)	0.50 (0.28)	0.56 (0.16)**
Proximity (distance to closest retailer) (miles)	1.39 (1.04)	1.19 (1.08)			1.19 (0.87)*	0.94 (0.33)***
Convenience stores						
Density (retailers/mi^2)	3.60 (2.58)	3.61 (2.48)	3.50 (2.27)	3.66 (1.27)	3.77 (2.16)	4.61 (1.48)***
Proximity (distance to closest retailer) (miles)	0.69 (0.45)	0.52 (0.44)**			0.48 (0.36)***	0.26 (0.10)***
Discount stores						
Density (retailers/mi^2)	0.42 (0.16)	0.44 (0.16)	0.42 (0.14)	0.39 (0.08)**	0.43 (0.14)	0.43 (0.08)
Proximity (distance to closest retailer) (miles)	1.25 (0.82)	1.08 (0.77)*			1.07 (0.59)*	0.90 (0.26)***
Limited service outlets						
Density (retailers/mi^2)	5.57 (7.99)	5.55 (7.66)	5.51 (6.88)	7.19 (3.33)**	6.66 (6.58)	10.89 (5.04)***
Proximity (distance to closest retailer) (miles)	0.83 (0.54)	0.67 (0.55)**			0.61 (0.47)***	0.28 (0.11)***
Full service restaurants						
Density (retailers/mi^2)	3.17 (5.26)	3.15 (5.04)	3.12 (4.55)	4.45 (2.42)**	3.96 (4.47)	6.40 (4.47)***
Proximity (distance to closest retailer) (miles)	0.97 (0.67)	0.77 (0.61)**			0.68 (0.46)***	0.35 (0.12)***
mRFEI	7.70 (3.10)	7.70 (3.23)	7.64 (2.90)	7.69 (1.44)	7.52 (2.67)	6.77 (1.63)**

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential census tract centroid to nearest outlet
[c] For proximity measures, this column displays distance from the residential address to nearest outlet
* $p<.05$; ** $p<.01$; *** $p<.0001$
Notes. mRFEI = modified Retail Food Environment Index

Table 2.3 Food shopping practices

	Supermarket (n=194)		Grocery store (n=54)		Convenience store (n=49)		Discount store (n=65)		Limited service outlet (n=167)		Full service restaurant (n=70)	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Unique retailers used (past month)	2.0	1.3-3.0	0.0	1.0-1.0	1.0	1.0-1.0	1.0	1.0-1.0	2.0	1.0-3.0	1.0	1.0-2.0
Trip frequency (per month)	4.6	2.0-8.7	1.5	1.0-2.0	17.3	6.7-30.4	5.0	3.0-13.0	3.6	1.5-8.1	1.0	0.3-2.0
Proximity from home (miles)	3.6	2.3-5.3	3.8	1.8-6.6	0.8	0.3-3.7	1.3	0.6-3.0	2.9	1.7-5.1	8.9	4.6-11.8
% used in residential census tract	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-100.0	0.0	0.0-50.0	0.0	0.0-0.0	0.0	0.0-0.0
% used in 1-mile road network buffer	0.0	0.0-0.0	0.0	0.0-0.0	100.0	0.0-100.0	0.0	0.0-100.0	0.0	0.0-25.0	0.0	0.0-0.0
% used in 2-mile road network buffer	0.0	0.0-50.0	0.0	0.0-100.0	100.0	0.0-100.0	100.0	0.0-100.0	33.3	0.0-100.0	0.0	0.0-0.0
% used in convex hull polygon	66.7	33.3-100.0	100.0	50.0-100.0	100.0	50.0-100.0	100.0	100.0-100.0	100.0	33.3-100.0	41.7	0.0-100.0
Amount spent grocery shopping (past week)	150.0	70.0-250.0	-	-	-	-	-	-	-	-	-	-
Amount spent eating out (past week)	-	-	-	-	-	-	-	-	22.0	7.0-50.0	-	-

Table 2.4 Association between food outlet density and food shopping practices (n=199)

	Unique supermarkets used (past month)			Supermarket trip frequency (past month)			Average distance from home to utilized supermarkets (miles)[a]			Any supermarkets used in tract[a,b]			Any supermarkets used in RNB1[a,b]			Any supermarkets used in RNB2[a,b]			Number of supermarkets used in CHP (out of total used)			Amount spent grocery shopping (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Supermarket density (per mi^2)																								
Residential census tract[a]	1.01	0.95	1.06	0.95	0.85	1.06	**0.88**	**0.80**	**0.97**	**1.28**	**1.07**	**1.54**	**1.48**	**1.23**	**1.79**	**1.24**	**1.09**	**1.40**	0.99	0.92	1.08	0.97	0.90	1.05
1-mile road network buffer[a]	1.00	0.95	1.06	0.99	0.89	1.09	**0.87**	**0.80**	**0.94**	**1.28**	**1.07**	**1.52**	**1.62**	**1.34**	**1.96**	**1.28**	**1.14**	**1.45**	1.02	0.95	1.09	0.93	0.86	1.01
2-mile road network buffer[a]	1.00	0.93	1.07	0.99	0.88	1.11	**0.86**	**0.78**	**0.94**	1.24	0.99	1.56	**1.69**	**1.34**	**2.15**	**1.32**	**1.15**	**1.52**	1.01	0.93	1.11	0.91	0.83	1.01
Convex hull polygon	1.07	1.00	1.14	1.10	0.96	1.26	**1.11**	**1.02**	**1.21**	1.04	0.87	1.25	1.15	0.84	1.59	0.98	0.82	1.17	0.96	0.87	1.05	0.96	0.84	1.10
Activity space points, unweighted	1.06	0.99	1.13	0.98	0.83	1.16	1.03	0.95	1.12	**1.50**	**1.12**	**2.00**	**1.65**	**1.17**	**2.33**	**1.25**	**1.04**	**1.50**	1.01	0.90	1.13	**0.84**	**0.73**	**0.95**
Activity space points, weighted (hours/month)	1.01	0.96	1.07	0.97	0.87	1.08	**0.92**	**0.86**	**0.99**	**1.35**	**1.14**	**1.59**	**1.74**	**1.40**	**2.16**	**1.27**	**1.12**	**1.44**	1.01	0.94	1.09	0.94	0.87	1.02

	Unique limited service outlets used (past month)			Limited service trip frequency (past month)			Average distance from home to utilized limited service outlets (miles)[a]			Any limited service outlets used in tract[a]			Any limited service outlets used in RNB1[a]			Any limited service outlets used in RNB2[a]			Number of limited service outlets used in CHP (out of total used)			Amount spent eating out (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Limited service outlet density (per mi^2)																								
Residential census tract[a]	**0.99**	**0.98**	**0.99**	1.00	0.98	1.01	0.98	0.96	1.00	1.01	0.95	1.07	**1.04**	**1.02**	**1.06**	**1.02**	**1.00**	**1.04**	**0.98**	**0.97**	**1.00**	1.01	0.99	1.03
1-mile road network buffer[a]	**0.99**	**0.98**	**1.00**	0.99	0.97	1.01	0.98	0.96	1.00	1.01	0.96	1.08	**1.04**	**1.02**	**1.06**	**1.02**	**1.01**	**1.04**	**0.98**	**0.97**	**0.99**	1.00	0.98	1.02
2-mile road network buffer[a]	**0.99**	**0.98**	**0.99**	1.00	0.97	1.02	0.98	0.96	1.00	1.00	0.93	1.09	**1.05**	**1.02**	**1.07**	**1.02**	**1.01**	**1.04**	**0.98**	**0.97**	**0.99**	1.01	0.99	1.04
Convex hull polygon	1.02	0.98	1.05	0.97	0.93	1.02	0.97	0.93	1.00	1.00	0.88	1.13	1.01	0.94	1.09	**1.03**	**1.00**	**1.06**	0.98	0.95	1.01	1.00	0.97	1.04
Activity space points, unweighted	1.00	0.98	1.01	0.98	0.95	1.00	1.00	0.97	1.03	0.98	0.90	1.07	1.03	0.98	1.09	1.00	0.97	1.03	0.99	0.97	1.01	1.03	1.00	1.06
Activity space points, weighted (hours/month)	**0.99**	**0.98**	**1.00**	0.98	0.96	1.01	0.98	0.96	1.00	1.02	0.96	1.09	**1.05**	**1.02**	**1.08**	**1.02**	**1.00**	**1.04**	**0.98**	**0.97**	**0.99**	1.00	0.92	1.09

[a] n=197 for the residential neighborhood environments because two participants did not share their home address

[b] Models estimated using Poisson regression with robust standard errors; all other models estimated using quasi-Poisson regression

Notes. Significant results are in bold. All models are adjusted for the characteristics listed in Table 1. RNB1 = 1-mile road network buffer; RNB2 = 2-mile road network buffer; CHP = convex hull polygon

Table 2.5 Association between distance to nearest food outlet and food shopping practices (n=199)

	Unique supermarkets used (past month)			Supermarket trip frequency (past month)			Average distance from home to utilized supermarkets (miles)[a]			Any supermarkets used in tract[a,b]			Any supermarkets used in RNB1[a,b]			Any supermarkets used in RNB2[a,b]			Number of supermarkets used in CHP (out of total used)			Amount spent grocery shopping (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Supermarket distance (miles)																								
Residential cenus tract centroid[a]	0.99	0.97	1.00	1.01	0.97	1.04	**1.03**	**1.02**	**1.05**	**0.85**	**0.73**	**0.98**	**0.68**	**0.60**	**0.77**	**0.81**	**0.76**	**0.87**	0.99	0.97	1.01	0.99	0.96	1.02
Residential address[a]	0.99	0.97	1.00	1.00	0.97	1.03	**1.04**	**1.03**	**1.06**	**0.91**	**0.85**	**0.98**	**0.61**	**0.53**	**0.71**	**0.82**	**0.78**	**0.86**	0.99	0.97	1.00	1.01	0.99	1.03
Activity space points, unweighted	0.98	0.94	1.03	1.06	0.96	1.16	1.03	0.97	1.08	**0.79**	**0.69**	**0.90**	**0.55**	**0.43**	**0.69**	**0.77**	**0.67**	**0.88**	0.96	0.90	1.03	1.06	0.98	1.15
Activity space points, weighted (hours/month)	0.99	0.97	1.01	1.00	0.97	1.04	**1.04**	**1.02**	**1.06**	**0.90**	**0.84**	**0.96**	**0.58**	**0.51**	**0.66**	**0.81**	**0.76**	**0.87**	0.98	0.96	1.00	1.01	0.98	1.04
	Unique limited service outlets used (past month)			Limited service trip frequency (past month)			Average distance from home to utilized limited service outlets (miles)[a]			Any limited service outlets used in tract[a]			Any limited service outlets used in RNB1[a]			Any limited service outlets used in RNB2[a]			Number of limited service outlets used in CHP (out of total used)			Amount spent eating out (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Limited service outlet distance (miles)																								
Residential cenus tract centroid[a]	1.02	0.98	1.05	0.98	0.94	1.03	**1.11**	**1.07**	**1.15**	0.93	0.74	1.16	0.90	0.73	1.10	0.93	0.85	1.01	0.96	0.92	1.00	0.96	0.90	1.04
Residential address[a]	1.02	0.99	1.06	1.02	0.97	1.06	**1.08**	**1.04**	**1.12**	0.86	0.71	1.05	**0.56**	**0.46**	**0.68**	**0.87**	**0.79**	**0.95**	0.96	0.92	1.01	1.00	0.94	1.06
Activity space points, unweighted	1.16	0.95	1.41	1.07	0.82	1.41	**1.52**	**1.18**	**1.96**	1.29	0.57	2.90	0.58	0.31	1.09	0.76	0.54	1.07	0.87	0.72	1.06	0.74	0.55	1.00
Activity space points, weighted (hours/month)	1.01	0.97	1.05	1.01	0.96	1.07	**1.08**	**1.04**	**1.13**	0.84	0.64	1.10	**0.50**	**0.37**	**0.66**	**0.86**	**0.76**	**0.96**	0.95	0.90	1.01	1.02	0.96	1.08

[a] n=197 for the residential neighborhood environments because two participants did not share their home address

[b] Models estimated using Poisson regression with robust standard errors; all other models estimated using quasi-Poisson regression

Notes. Significant results are in bold. All models are adjusted for the characteristics listed in Table 1. RNB1 = 1-mile road network buffer; RNB2 = 2-mile road network buffer; CHP = convex hull polygon

Table 2.6: Appendix, Association between mRFEI and food shopping practices (n=199)

	Unique supermarkets used (past month)			Supermarket trip frequency (past month)			Average distance from home to utilized supermarkets (miles)[a]			Any supermarkets used in tract[a,b]			Any supermarkets used in RNB1[a,b]			Any supermarkets used in RNB2[a,b]			Number of supermarkets used in CHP (out of total used)			Amount spent grocery shopping (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Residential census tract mRFEI[a]	1.02	1.00	1.04	1.02	0.98	1.06	0.98	0.96	1.01	1.03	0.94	1.12	0.91	0.82	1.01	0.97	0.92	1.02	0.99	0.96	1.02	1.00	0.96	1.04
1-mile road network buffer mRFEI[a]	**1.02**	**1.00**	**1.04**	1.03	0.99	1.06	**0.98**	**0.96**	**1.00**	1.04	0.95	1.13	0.95	0.87	1.03	1.00	0.95	1.05	0.99	0.96	1.02	1.00	0.97	1.04
2-mile road network buffer mRFEI[a]	**1.02**	**1.00**	**1.05**	1.02	0.99	1.06	**0.97**	**0.95**	**0.99**	1.05	0.95	1.16	0.95	0.86	1.04	1.00	0.94	1.06	0.99	0.96	1.02	1.00	0.97	1.04
Convex hull polygon mRFEI	1.01	0.98	1.05	1.03	0.96	1.12	1.00	0.96	1.05	**1.13**	**1.01**	**1.25**	1.05	0.84	1.30	0.95	0.86	1.05	1.04	0.98	1.11	0.97	0.91	1.04
Activity space points, unweighted mRFEI	1.02	0.99	1.06	1.06	0.99	1.13	0.97	0.93	1.02	1.16	1.00	1.35	0.99	0.83	1.19	0.97	0.88	1.07	0.98	0.93	1.04	0.95	0.90	1.01
Activity space points, weighted (hours/month) mRFEI	1.02	0.99	1.04	1.04	1.00	1.09	**0.97**	**0.94**	**1.00**	1.02	0.93	1.12	0.92	0.83	1.02	0.98	0.92	1.04	1.00	0.96	1.03	1.01	0.97	1.05
	Unique limited service outlets used (past month)			Limited service trip frequency (past month)			Average distance from home to utilized limited service outlets (miles)[a]			Any limited service outlets used in tract[a]			Any limited service outlets used in RNB1[a]			Any limited service outlets used in RNB2[a]			Number of limited service outlets used in CHP (out of total used)			Amount spent eating out (past week)		
	exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI		exp(β)	95% CI	
Residential census tract mRFEI[a]	1.02	0.99	1.04	1.02	0.98	1.07	0.98	0.94	1.02	0.98	0.88	1.09	0.92	0.84	1.00	0.97	0.92	1.02	1.01	0.99	1.04	0.99	0.95	1.05
1-mile road network buffer mRFEI[a]	1.02	0.99	1.04	1.02	0.97	1.07	0.97	0.93	1.01	0.99	0.90	1.10	0.93	0.86	1.01	0.98	0.93	1.03	1.02	0.99	1.04	1.00	0.96	1.05
2-mile road network buffer mRFEI[a]	1.02	0.99	1.04	1.03	0.98	1.08	0.97	0.92	1.02	1.01	0.90	1.14	0.94	0.86	1.03	0.98	0.93	1.04	1.02	0.99	1.05	1.02	0.96	1.08
Convex hull polygon mRFEI	1.01	0.95	1.08	1.05	0.96	1.14	1.06	0.99	1.14	1.04	0.81	1.32	0.94	0.77	1.16	0.93	0.84	1.01	1.04	0.98	1.10	1.00	0.91	1.10
Activity space points, unweighted mRFEI	1.02	0.98	1.07	1.05	0.98	1.14	0.98	0.90	1.06	1.07	0.87	1.31	0.99	0.84	1.17	0.99	0.90	1.09	1.03	0.97	1.09	0.99	0.91	1.08
Activity space points, weighted (hours/month) mRFEI	1.02	0.99	1.04	1.04	0.99	1.09	0.97	0.92	1.02	0.98	0.86	1.13	0.94	0.85	1.03	0.97	0.92	1.03	1.03	1.00	1.06	1.00	0.94	1.07

[a] n=197 for the residential neighborhood environments because two participants did not share their home address

[b] Models estimated using Poisson regression with robust standard errors; all other models estimated using quasi-Poisson regression

Notes. Significant results are in bold. All models are adjusted for the characteristics listed in Table 1. mRFEI = modified Retail Food Environment Index; RNB1 = 1-mile road network buffer; RNB2 = 2-mile road network buffer; CHP = convex hull polygon

References

1. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med.* 2009;36(1):74-81.
2. Black C, Moon G, Baird J. Dietary inequalities: What is the evidence for the effect of the neighbourhood food environment? *Health & Place.* 2014;27:229-242.
3. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P. Are neighbourhood food resources distributed inequitably by income and race in the USA? Epidemiological findings across the urban spectrum. *BMJ Open.* 2012;2(2):e000698.
4. Reinvestment Fund. About the Healthy Food Financing Initiative. https://www.investinginfood.com/about-hffi/. Accessed March 25, 2019.
5. Sturm R, Hattori A. Diet and obesity in Los Angeles County 2007–2012: Is there a measurable effect of the 2008 "Fast-Food Ban"? *Soc Sci Med.* 2015;133:205-211.
6. McCormack LA, Laska MN, Larson NI, Story M. Review of the Nutritional Implications of Farmers' Markets and Community Gardens: A Call for Evaluation and Research Efforts. *J Am Diet Assoc.* 2010;110(3):399-408.
7. Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CAM. The relationship of the local food environment with obesity: A systematic review of methods, study quality, and results. *Obesity.* 2015;23(7):1331-1344.
8. Feng J, Glass TA, Curriero FC, Stewart WF, Schwartz BS. The built environment and obesity: A systematic review of the epidemiologic evidence. *Health & Place.* 2010;16(2):175-190.
9. Lake AA. Neighbourhood food environments: food choice, foodscapes and planning for health. *Proceedings of the Nutrition Society.* 2018;77(3):239-246.
10. Lucan SC. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *J Acad Nutr Diet.* 2015;115(2):205-212.

11. Matthews SA, Yang T-C. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist.* 2013.

12. Zenk SN, Schulz AJ, Matthews SA. Activity space environment and eating and physical activity behaviors: A pilot study. *Health and Place.* 2011;17:1150 - 1161.

13. Kestens Y, Lebel A, Daniel M, Thériault M, Pampalon R. Using experienced activity spaces to measure foodscape exposure. *Health & Place.* 2010;16(6):1094-1103.

14. Clary C, Matthews SA, Kestens Y. Between exposure, access and use: Reconsidering foodscape influences on dietary behaviours. *Health & Place.* 2017;44:1-7.

15. Crawford TW, Jilcott Pitts SB, McGuirt JT, Keyserling TC, Ammerman AS. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health & Place.* 2014;30:215-225.

16. Ver Ploeg M, Mancino L, Todd JE, Clay DM, Scharadin B. *Where Do Americans Usually Shop for Food and How Do They Travel To Get There? Initial Findings From the National Household Food Acquisition and Purchase Survey.* United States Department of Agriculture, Economic Research Service;2015.

17. Hillier A, Cannuscio CC, Karpyn A, McLaughlin J, Chilton M, Glanz K. How Far Do Low-Income Parents Travel to Shop for Food? Empirical Evidence from Two Urban Neighborhoods. *Urban Geography.* 2011;32(5):712-729.

18. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and Supermarket Access: Proximity or Price? *American journal of public health.* 2012;102(8):e74-e80.

19. LeDoux TF, Vojnovic I. Going outside the neighborhood: The shopping patterns and adaptations of disadvantaged consumers living in the lower eastside neighborhoods of Detroit, Michigan. *Health & Place.* 2013;19:1-14.

20. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. *Health & place.* 2012;18(5):1172-1187.

21. Ghosh-Dastidar B, Cohen D, Hunter G, et al. Distance to Store, Food Prices, and Obesity in Urban Food Deserts. *American journal of preventive medicine.* 2014;47(5):587-595.

22. Shannon J. Beyond the Supermarket Solution: Linking Food Deserts, Neighborhood Context, and Everyday Mobility. *Annals of the American Association of Geographers.* 2016;106(1):186-202.

23. Zenk SN, Odoms-Young AM, Dallas C, et al. "You have to hunt for the fruits, the vegetables": environmental barriers and adaptive strategies to acquire food in a low-income African American neighborhood. *Health education & behavior : the official publication of the Society for Public Health Education.* 2011;38(3):282-292.

24. Cannuscio CC, Hillier A, Karpyn A, Glanz K. The social dynamics of healthy food shopping and store choice in an urban environment. *Social Science & Medicine.* 2014;122:13-20.

25. Stern D, Robinson WR, Ng SW, Gordon-Larsen P, Popkin BM. US Household Food Shopping Patterns: Dynamic Shifts Since 2000 And Socioeconomic Predictors. *Health Affairs.* 2015;34(11):1840-1848.

26. Liese AD, Bell BA, Barnes TL, et al. Environmental influences on fruit and vegetable intake: results from a path analytic model. *Public Health Nutrition.* 2014;17(11):2595-2604.

27. Jilcott Pitts SB, McGuirt JT, Carr LJ, Wu Q, Keyserling TC. Associations between Body Mass Index, Shopping Behaviors, Amenity Density, and Characteristics of the Neighborhood Food Environment among Female Adult Supplemental Nutrition Assistance Program (SNAP) Participants in Eastern North Carolina. *Ecology of Food and Nutrition.* 2012;51(6):526-541.

28. Thompson C, Cummins S, Brown T, Kyle R. Understanding interactions with the food environment: An exploration of supermarket food shopping routines in deprived neighbourhoods. *Health & Place.* 2013;19:116-123.

29. Gustafson A, Christian JW, Lewis S, Moore K, Jilcott S. Food venue choice, consumer food environment, but not food venue availability within daily travel patterns are associated with dietary intake among adults, Lexington Kentucky 2011. *Nutrition Journal.* 2013;12(1):1-11.

30. Zenk SN, Schulz AJ, Hollis-Neely T, et al. Fruit and Vegetable Intake in African Americans: Income and Store Characteristics. *American Journal of Preventive Medicine.* 2005;29(1):1-9.

31. Aggarwal A, Cook AJ, Jiao J, et al. Access to Supermarkets and Fruit and Vegetable Consumption. *American journal of public health.* 2014;104(5):917-923.

32. Inagami S, Cohen DA, Finch BK, Asch SM. You Are Where You Shop: Grocery Store Locations, Weight, and Neighborhoods. *American Journal of Preventive Medicine.* 2006;31(1):10-17.

33. Liese AD, Ma XN, Hutto B, Sharpe PA, Bell BA, Wilcox S. Food Shopping and Acquisition Behaviors in Relation to BMI among Residents of Low-Income Communities in South Carolina. *International Journal of Environmental Research and Public Health.* 2017;14(9):1075.

34. Lear SA, Gasevic D, Schuurman N. Association of supermarket characteristics with the body mass index of their shoppers. *Nutrition Journal.* 2013;12(1):117.

35. Dubowitz T, Zenk SN, Ghosh-Dastidar B, et al. Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutr.* 2015;18(12):2220-2230.

36. Cannuscio CC, Tappe K, Hillier A, Buttenheim A, Karpyn A, Glanz K. Urban Food Environments and Residents' Shopping Behaviors. *American Journal of Preventive Medicine.* 2013;45(5):606-614.

37. Laska MN, Hearst MO, Forsyth A, Pasch KE, Lytle L. Neighbourhood food environments: are they associated with adolescent dietary intake, food purchases and weight status? *Public Health Nutrition.* 2010;13(11):1757-1763.

38. Widener MJ, Minaker LM, Reid JL, Patterson Z, Ahmadi TK, Hammond D. Activity space-based measures of the food environment and their relationships to food purchasing behaviours for young urban adults in Canada. *Public Health Nutrition.* 2018;21(11):2103-2116.

39. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in Obesity Among Adults in the United States, 2005 to 2014. *JAMA.* 2016;315(21):2284-2291.

40. Rehm CD, Peñalvo JL, Afshin A, Mozaffarian D. Dietary intake among us adults, 1999-2012. *JAMA.* 2016;315(23):2542-2553.

41. Bisogni CA, Connors M, Devine CM, Sobal J. Who we are and how we eat: a qualitative study of identities in food choice. *J Nutr Educ Behav.* 2002;34.

42. Hardcastle SJ, Blake N. Influences underlying family food choices in mothers from an economically disadvantaged community. *Eat Behav.* 2016;20:1-8.

43. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine.* 2012;43(4):440-450.

44. Kestens Y, Thierry B, Shareck M, Steinmetz-Wood M, Chaix B. Integrating activity spaces in health research: Comparing the VERITAS activity space questionnaire with 7-day GPS tracking and prompted recall. *Spatial and Spatio-temporal Epidemiology.* 2018;25:1-9.

45. Zenk SN, Kraft AN, Jones KK, Matthews SA. Convergent validity of an activity-space survey for use in health research. *Health & Place.* 2019;56:19-23.

46. Jones KK, Zenk SN, Tarlov E, Powell LM, Matthews SA, Horoi I. A step-by-step approach to improve data quality when using commercial business lists to characterize retail food environments. *BMC Res Notes.* 2017;10(1):35.

47. U.S. Bureau of Labor Statistics. Average hours per day spent in selected activities by employment status and sex https://www.bls.gov/charts/american-time-use/activity-by-emp.htm. Published 2017. Accessed April 4, 2019.

48. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR. Associations of the Local Food Environment with Diet Quality—A Comparison of Assessments based on Surveys and Geographic Information Systems: The Multi-Ethnic Study of Atherosclerosis. *American Journal of Epidemiology.* 2008;167(8):917-924.

49. Jones-Smith JC, Karter AJ, Warton EM, et al. Obesity and the food environment: income and ethnicity differences among people with diabetes: the Diabetes Study of Northern California (DISTANCE). *Diabetes Care.* 2013;36(9):2697-2705.

50. Moore K, Diez Roux AV, Auchincloss A, et al. Home and work neighbourhood environments in relation to body mass index: the Multi-Ethnic Study of Atherosclerosis (MESA). *J Epidemiol Community Health.* 2013;67(10):846-853.

51. CDC. Census Tract Level State Maps of the Modified Retail Food Environment Index (mRFEI). In.

52. Sherman JE, Spencer J, Preisser JS, Gesler WM, Arcury TA. A suite of methods for representing activity space in a healthcare accessibility study. *International Journal of Health Geographics.* 2005;4:24-24.

53. Christian WJ. Using geospatial technologies to explore activity-based retail food environments. *Spatial and Spatio-temporal Epidemiology.* 2012;3(4):287-295.

54. City of Atlanta. Zoning Ordinance Update for the City of Atlanta. https://www.zoningatl.com/. Published 2019. Accessed April 6, 2019.

55. Li J, Kim C. Measuring Individuals' Spatial Access to Healthy Foods by Incorporating Mobility, Time, and Mode: Activity Space Measures. *The Professional Geographer.* 2018;70(2):198-208.

56. DiSantis KI, Grier SA, Odoms-Young A, et al. What “Price” Means When Buying Food: Insights From a Multisite Qualitative Study With Black Americans. *American journal of public health.* 2013;103(3):516-522.

57. Pitt E, Gallegos D, Comans T, Cameron C, Thornton L. Exploring the influence of local food environments on food behaviours: a systematic review of qualitative literature. *Public Health Nutrition.* 2017;20(13):2393-2405.

58. Song H-J, Gittelsohn J, Kim M, Suratkar S, Sharma S, Anliker J. A corner store intervention in a low-income urban community is associated with increased availability and sales of some healthy foods. *Public Health Nutrition.* 2009;12(11):2060-2067.

59. Garza KB, Ding M, Owensby JK, Zizza CA. Impulsivity and Fast-Food Consumption: A Cross-Sectional Study among Working Adults. *Journal of the Academy of Nutrition and Dietetics.* 2016;116(1):61-68.

60. Dave JM, An LC, Jeffery RW, Ahluwalia JS. Relationship of attitudes toward fast food and frequency of fast-food intake in adults. *Obesity.* 2009;17(6):1164-1170.

61. Glanz K, Sallis JF, Saelens BE, Frank LD. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. *Am J Prev Med.* 2007;32.

62. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Reports.* 2001;116(5):404-416.

63. Massey DS, Denton NA. The dimensions of residential segregation. *Social Forces.* 1988;67:281 - 315.

64. Jones M, Pebley A. Redefining Neighborhoods Using Common Destinations: Social Characteristics of Activity Spaces and Home Census Tracts Compared. *Demography.* 2014;51(3):727-752.

65. Chaix B. Geographic Life Environments and Coronary Heart Disease: A Literature Review, Theoretical Contributions, Methodological Updates, and a Research Agenda. *Annu Rev Public Health.* 2009;30(1):81-105.

66. Fleischhacker SE, Evenson KR, Sharkey J, Pitts SBJ, Rodriguez DA. Validity of Secondary Retail Food Outlet Data: A Systematic Review. *American Journal of Preventive Medicine.* 2013;45(4):462-473.

Chapter 3: Leaving the food desert: An activity space approach to understanding how food access and food purchasing practices are associated with dietary intake and BMI among low-income African American women in Atlanta, GA

Abstract

Background: Understanding the pathways through which food environments affect diet- and weight-related health is critical to the development of effective interventions. The inconclusive nature of existing evidence may be due to an emphasis on the residential food environment and insufficient attention to where people actually purchase food.

Objective: We used an activity space approach, defined by the full extent of locations people visit on a routine basis, to examine: 1) whether associations between food access, dietary intake, and BMI differ by the use of residential versus activity space definitions of the food environment, and 2) whether food purchasing practices are associated with dietary intake and BMI.

Methods: We recruited African American women between the ages of 18-44 from two safety-net health care clinics in Atlanta, GA. We used an adapted version of the VERITAS questionnaire to collect activity space data. We obtained retail food outlet data from the Georgia Departments of Public Health and Agriculture, and assessed three dimensions of food access: density, proximity, and quality. We measured dietary intake using a 26-item food frequency questionnaire, and abstracted measured weight and height from electronic medical records. We used generalized estimating equations to estimate adjusted associations between exposures and outcomes, controlling for the correlation of women within residential census tracts.

Results: Being located farther away from "unhealthy" outlets, including convenience stores, discount stores, and limited service outlets, was associated with lower BMI. Neither food outlet density nor quality was associated with dietary intake or BMI. Associations did not differ by the use of residential or activity space definitions. Food shopping practices, rather than food access, were the most salient predictors of dietary intake. Using a larger number of limited service outlets, using limited service outlets more frequently, and spending more money eating out were associated with a less healthful dietary pattern.

Conclusions: Examining the food environments to which women were exposed as well as their food purchasing practices provided a more complete picture of the pathways through which food environments may affect diet- and weight-related health. Results highlight the importance of examining multiple dimensions of food access and considering how the salience of each dimension may vary by outlet type. Additional research is needed to understand how the relative importance of residential neighborhoods and activity spaces may vary across populations and places.

Introduction

Ecological models of health recognize that health-promoting behaviors are most likely to occur within supportive and enabling environments.[1] For many residents of socioeconomically disadvantaged and racial and ethnic minority communities in the United States, the environments in which diet-related decisions are made often provide limited access to affordable, healthy foods and abundant access to low-cost, nutrient-poor options.[2-5] These well-evidenced disparities in the food environment are theorized to help explain the substantially higher prevalence of poor diet quality and obesity among low-income and racial and ethnic minority populations.[6-10]

To facilitate the development of evidence-based solutions that improve food environments and make them more supportive of healthy eating, researchers have spent the past several decades seeking to identify the specific pathways through which food environments affect health. However, despite amassing a considerable body of research, the evidence base remains inconclusive. Recent systematic reviews examining associations between the food environment and health found that 76% of associations with obesity[11] and 67% of associations with dietary intake[12] were null. While some findings are suggestive of a negative association between supermarket access and obesity, and a positive association between fast food access and obesity, a clear and consistent evidence-base has yet to be established.[11,13]

Like most place-based health research, food environment researchers have primarily relied on residential neighborhoods to delineate the environments to which people are exposed. However, in reality, people encounter a multiplicity of environments as they move through their daily lives: going to work, visiting friends and family, shopping, dropping children off at school, and more. As a result, relying on residential neighborhood boundaries to define exposure may substantially misclassify individual experiences of the food environment. This issue, also referred to as the uncertain geographic context problem[14] or the “local” trap,[15] has become a widely cited challenge in food environment research.[16-19] Increasingly, researchers have argued for the use of “activity space” approaches, which seek to measure the totality of places people visit on a routine basis thus providing a more accurate characterization of the environments to which they are exposed.[20-24]

A small number of studies have demonstrated how using an activity space approach may offer additional insight into the pathways through which food environments affect health. Among low-income African American women in Detroit, Zenk et al.[23] found that higher fast food outlet density in the activity space was associated with higher saturated fat intake and lower whole grain intake, while fast food outlet density in the residential neighborhood was not associated with diet. Among adults in Montreal and Quebec City, Kestens et al.[25] found that activity space measures of the food environment were more strongly associated with weight outcomes among men, while residential neighborhood food environments were more strongly associated with weight outcomes among women. Additional research is needed to understand differences betwen residential neighborhood and activity space measures of the food environment, including how different approaches to measuring and representing activity spaces may affect results.

An additional strength of activity space approaches is that they can capture how people *interact* with their food environments, including where, when, and how they acquire food. Without data on actual food purchasing practices, existing research often relies on the assumption that the food outlets to which people are exposed accurately represent the food outlets they use. However, food environments, particularly in urban areas, often contain numerous options, both healthy and unhealthy, and it is unlikely that people use all of the outlets to which they are exposed.[16,26,27] A greater focus on individual decision-making in the face of multiple options,[16] and recognition of the diverse factors that affect outlet choice, such as affordability, accessiblity from public transportation, and the availability of culturally relevant foods,[28-30] may offer a more true-to-life picture of how people and places interact to affect health.

Understanding how people interact with their food environments has become increasingly important as researchers seek to determine why recent efforts to improve food environments in underserved communities have had few appreciable effects on diet- and weight-related health.[31] While reducing population-level disparities in dietary quality and obesity remains the overarching public health objective, identifying environmental and behavioral factors that contribute to diet- and weight-related differences *within* underserved communities may help improve intervention effectiveness.[32] Recent research has found considerable variability in the food environments and food shopping practices of low-income and racial and ethnic minority populations.[3332] A greater understanding of these internal differences may improve the targeting and tailoring of food environment interventions.

The present study uses an activity space approach to examine the food environments and food purchasing behaviors of low-income African American women in Atlanta, Georgia. We aim to advance understanding of how food environments affect health by providing a more comprehensive and accurate picture of the food environments to which women are exposed and the food purchasing decisions they make when confronted with multiple options. We sought to answer two primary research questions:

1. (How) do associations between food access and body mass index (BMI)/dietary intake differ by the use of residential versus activity space definitions of the food environment? We assessed three dimensions of food access including availability, geographic proximity, and quality, and four types of food outlets including supermarkets, convenience stores/pharmacies, discount general merchandise stores, and limited service outlets.
2. (How) are food shopping practices associated with BMI/dietary intake? Does examining how women interact with their food environments offer new or complementary insight beyond what is gleaned from examining the food environments to which they are exposed?

Methods

Population and setting. Women were eligible for participation if they were between the ages of 18-44, African American, residing with at least one child under the age of 18, and able to comprehend written and spoken English (n=203). Women confirmed as currently pregnant were excluded due to potential differences in dietary intake, weight gain, and routine spatial behavior. We chose to focus on women living with children as they commonly hold primary responsibility for household food purchasing and preparation, and play an important role in shaping the diet- and weight-related health of their families.[34,35] Women were recruited from the waiting rooms of two safety net care clinics in Atlanta, Georgia, USA. Study visits lasted for approximately 45 minutes to one hour, and women were compensated $20 for their time. We defined our study area as the Atlanta Regional Commission's (ARC) 10-county area, which includes Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry, and Rockdale counties. The Emory University Institutional Review Board and the Grady Health System Research Oversight Committee approved all study procedures.

Data sources. ***Activity space questionnaire.*** Activity space data were collected using an adapted version of the Visualization and Evaluation of Routine Itineraries, Travel destinations, and Activity Spaces (VERITAS) questionnaire. VERITAS is an interviewer-administered web-based questionnaire with embedded Google Maps functionality, which enables the interviewer and participant to search for, identify, and input each activity location directly on the map. Participants begin by identifying key anchor points in their routine travels, including home, work, and school. Participants are then asked to provide the name and address of locations they have visited at least once in the previous month. To facilitate recall, participants are prompted through a series of questions about 21 different types of activity locations, including food-seeking locations, commerce or service locations, social locations, family-related locations, and health services locations. Participants are also asked to provide information on visit frequency, average visit duration, and typical mode of transportation for each location. Up to five locations can be input for each of the 21 activity location types. Several activity types have a reference period of the past year (e.g. health services locations).

Socio-demographic and dietary intake survey. Prior to administering the activity space questionnaire, we collected data on dietary intake, the amount spent on food during the previous week, and socio-demographic characteristics using an interviewer-administered web-based survey.

Electronic medical records. We abstracted data on BMI and smoking status from electronic medical records. Whenever possible, we used the BMI calculated from height and weight measured at the medical appointment occurring on the same date as the study visit. Health care providers record smoking status at each medical appointment as "never smoker", "former smoker", or "current smoker". There were

21 participants (11%) who did not have their weight and/or height measured on the date of the study visit. For these participants, we recorded the BMI from their most recent appointment. For the majority of these participants (n=13) this was within one month of the study visit, and for the remaining participants this was within three (n=5) or six (n=3) months of the study visit. Similarly, 44 participants (22%) were not asked about their smoking status on the date of the study visit. For these participants, we recorded smoking status from the most recent appointment at which it was updated. For the majority of these participants (n=27) this was within three months of the study visit, and for the remaining participants this was within six (n=9) or twelve (n=8) months of the study visit.

Retail food environment data. We obtained data on the locations of retail food outlets within the study area through the Georgia Departments of Public Health (GDPH) and Agriculture (GDA). Additional detail on our data cleaning protocol has been described elsewhere [cite paper 1]. Briefly, data cleaning involved four primary steps: 1) geocoding address data, 2) removing outlets deemed ineligible for inclusion (e.g. not open to the public), 3) removing duplicate records, and 4) classifying outlets into one of six categories: supermarkets, grocery stores, convenience stores/pharmacies, discount general merchandise stores (e.g. dollar stores), limited service outlets (e.g. fast food, coffee shops, ice cream parlors), and full service restaurants. In the present study, we examined four types of outlets: one "healthy" outlet type, supermarkets, and three "unhealthy" outlet types, convenience stores/pharmacies, discount general merchandise stores, and limited service outlets. We did not examine grocery stores or full service restaurants due to insufficient theoretical justification for treating them as "healthy" or "unhealthy" outlets.

In step one, we used Google Maps' Geocoding API to geocode all address data, and achieved a 99.9% match rate. In step two, we removed outlets deemed ineligible for inclusion because they were not open to the public, did not have a permanent retail location, or were not primarily visited for the purpose of obtaining food. We identified these outlets through a combination of existing categories provided by GDPH and GDA, key word searches, and hand searching. We then removed duplicate records by identifying retailers with the same name located at the same latitude and longitude, and by hand searching retailers located at the latitude and longitude with similar names, but not an exact name match. Finally, we classified outlets into one of six categories using several strategies including, existing categories provided by GDPH and GDA, specific outlet names compiled by Jones et al.[36], and a GDPH variable indicating whether all food served at the retailer was pre-processed or pre-cooked. One of the ten counties in our study area did not include a variable distinguishing limited service and full service restaurants. Using the other strategies describe above, we were able to classify 39% of the retailers in this county. We removed the remaining unclassified retailers from the analytic dataset because only 1% of activity space locations fell within this county.

Area-level characteristics. We obtained data on census block group-level median household income from the 2017 American Community Survey for use as a control variable in adjusted analyses.

Measures. ***Defining the residential neighborhood and activity space environments*.** The residential neighborhood and activity space environments were each defined in two ways. The residential neighborhood was defined as: 1) the census tract in which the participant resides, and 2) the 1-mile road network buffer surrounding the participant's residential address. The activity space environment was defined as: 1) the set of points representing each of the participant's activity locations, and 2) the set of points representing each of the participant's activity locations weighted for the frequency and duration of each visit (hours per month). The VERITAS questionnaire does not ask participants to report the number of hours per day spent at home. We imputed this value using gender- and employment status-specific estimates from the American Time Use Survey (11.7 and 13.5 hours per day for employed and unemployed participants, respectively). Using multiple definitions of each environment allows us to examine not only whether results differ between residential neighborhood and activity space environments, but also whether any observed differences are sensitive to how the environment is defined.

Exposure variables. *Food access.* Food access is a multi-dimensional construct that can be defined in various ways. We examined three dimensions of food access: availability, geographic proximity, and quality. We calculated availability and geographic proximity separately for each of the four outlet categories. Availability was defined as the density of outlets per square mile. We used kernel density estimation (KDE), with a one-mile bandwidth, to create a continuous surface of outlet density per square mile for each outlet category. We then overlaid the participant's residential census tract, 1-mile road network buffer, and activity locations on the continuous surface. For the residential census tract and 1-mile road network buffer, we extracted the average outlet density within each polygon. For the unweighted and weighted activity locations, we extracted the outlet density at each point and calculated an average across all of the activity locations for each participant.

We defined geographic proximity as the road network distance to the nearest outlet. For the residential census tract we calculated distance from the census tract centroid, for the road network buffer we calculated distance from the participant's residential address, and for the unweighted and weighted activity locations we calculated distance from each point to the nearest outlet and then calculated an average across all of the activity locations for each participant.

We assessed the quality of the food environment using the Centers for Disease Control and Prevention's (CDC) modified retail food environment index (mRFEI).[37] The mRFEI is calculated as the number of healthy food retailers divided by the number of healthy and unhealthy retailers in a given area. We classified supermarkets as healthy retailers and convenience stores/pharmacies, discount general merchandise stores, and limited service outlets as unhealthy retailers. We used the KDE approach described above to create continuous mRFEI surfaces and extract values for each residential neighborhood and activity space environment.

Importantly, for all measures of access in the activity space we addressed the issue of selective daily mobility bias, which can occur when there are unmeasured factors associated with the locations a person chooses to visit as well as the health behaviors or outcomes of interest.[24] This form of bias can be minimized by excluding activity points that match the environmental exposure of interest when calculating measures of food access in the participant's activity space. For example, when calculating convenience store density in a participant's activity space, we excluded activity points that were convenience stores. In doing so, if we observe an association between convenience store density and obesity, for example, we can be more certain that there is a true association between the environmental exposure and the outcome, rather than a spurious association driven by another factor that is associated with a woman's propensity to shop at a convenience store and her weight status.

Food shopping practices. We used the activity space data to calculate the number of unique retailers participants used in the past month, the trip frequency, and the average distance from the participant's residential address to the utilized retailers. All food shopping practice measures were calculated separately for each of the four retailer categories (supermarkets, convenience stores/pharmacies, discount general merchandise stores, and limited service outlets). We also examined *where* participants obtained food by assessing whether any utilized retailers fell within the boundaries of their residential census tract (yes/no), 1-mile road network buffer (yes/no), and 2-mile road network buffer (yes/no). We also calculated the percentage of utilized retailers located within the convex hull polygon. This measure allows us to assess the extent to which participants deviate from their routine travel to utilize food retailers. It is constructed by creating a convex hull polygon of all of the participant's activity locations except locations belonging to the type of food retailer in question. A higher percentage of utilized retailers within the convex hull polygon indicates greater accessibility because participants do not need to deviate from their routine travels to obtain food. Finally, women reported the amount spent on groceries and eating out during the previous week. Due to the presence of extreme outliers, we Winsorized the following variables at the 95th percentile: frequency of supermarket trips, supermarket proximity, limited service outlet proximity, amount spent on groceries, and amount spent eating out.

Outcome variables. *Dietary intake*. We measured dietary intake using the Dietary Risk Assessment (DRA). The DRA is a 26-item food frequency questionnaire (FFQ) that measures usual intake of foods and beverages associated with cardiovascular disease risk.[39,40] A single dietary intake score (ranging from 0-52) is obtained by summing the scores from four subsections: 1) nuts, oils, dressings, and spreads; 2) vegetables, fruit, whole grains, and beans; 3) drinks, desserts, snacks, eating out, and salt; and 4) fish, meat, poultry, dairy, and eggs. A higher score represents a healthier dietary pattern. Although the score can be dichotomized into "desirable" or "not desirable" we treated the score as continuous in all analyses as only five participants fell within the desirable category. The DRA was validated against the Fred Hutchinson Cancer Research Center FFQ (FHCRC-FFQ) in a sample of low-income, midlife, southern, African American women. Correlations between total DRA score and three FHCRC-FFQ diet quality scores ranged from 0.57 to 0.60.[39]

BMI. We abstracted BMI from the electronic medical records where it is automatically calculated from the patient's measured weight and height. We treated BMI as a continuous variable in all analyses.

Control variables. The following control variables were included in adjusted analyses: age (continuous); education (less than high school; high school diploma or GED; some college or technical school; Associate's degree or higher); employment status (full-time; part-time; unemployed, seeking employment; unemployed, not seeking employment); marital status (currently married; not married, living with a partner; never married; divorced, widowed, or separated); household size (continuous); annual income (less than $5,000; $5,000-$9,999; $10,000-$19,999; $20,000-$29,999; greater than $30,000); car ownership (yes; no); receipt of Supplemental Nutrition Assistance Program (SNAP) benefits (yes; no); smoking status (current smoker; former smoker; never smoker); and area-level median household income (continuous). In order to control for area-level median household income in all models, we created separate median household income variables for each of the four residential neighborhood and activity space environments. Using census block group-level median household income data, we created a continuous KDE surface representing the spatially varying median household income across the study area. We then extracted the average values for each polygon and set of activity space points as described above.

Analysis. We excluded four participants due to incomplete data or data quality concerns, resulting in a final analytic sample of 199 women. In addition, two women declined to share their residential address. All measures of the residential environment reflect a sample size of 197 women. We excluded seven women who were missing height and/or weight from all models where BMI was the outcome. We imputed median and modal values for the small amount of missing covariate data. Eight activity locations (out of 3,184) were missing information on the frequency and/or duration of the visit. For each of these locations we imputed the median value specific to the activity type (e.g. doctor's office, supermarket, family member's home). For the one participant who did not report her annual income, we imputed the modal value of 'less than $5,000', and for the eight participants missing smoking status, we imputed the modal value of 'never smoker'.

We used generalized estimating equations (GEE) to estimate the adjusted associations between: 1) food shopping practices and dietary intake, 2) food shopping practices and BMI, 3) food access and dietary intake, and 4) food access and BMI, controlling for the correlation of women within residential census tracts. We adjusted all models for the control variables listed above. For models estimating the association between food access and dietary intake/BMI, we examined two sets of control variables. In the first set of models, we adjusted for the control variables listed above. In the second set of models, we adjusted for an additional control variable: for models estimating the association between supermarket access and dietary intake/BMI, we adjusted for the average density of "unhealthy" retailers in the same environment (i.e. convenience stores, discount stores, and limited service outlets), and for models estimating the association between access to each type of "unhealthy" retailer and dietary intake/BMI, we adjusted for the density of "healthy" retailers in the same environment (i.e. supermarkets). We estimated this second set of models in an attempt to address the possibility that healthy and unhealthy retailers may be located next to one another in shopping centers, strip malls, and commercial areas.

Model collinearity was assessed with the Variance Inflation Factor (VIF). Using a VIF cut-off of greater than or equal to four, we found no evidence of collinearity. Statistical tests were considered significant at $p<0.05$. ArcGIS Network Analyst (Version 10.6. Redlands, California: Environmental Systems Research Institute, Inc.) was used to calculate road network distances, and all other analyses were conducted in R version 3.5.1.

Results

Women were, on average, 32 years old (SD=6.7) (Table 1). The majority had a high school diploma (42.7%) or less (13. 6%), over half were employed (full-time=37.2%, part-time=19.6%), and most women earned less than $30,000 per year. Nearly three quarters of women were single and had never been married, and the mean household size was four people (SD=1.6). The mean DRA score was

28.5 (SD=5.2) indicating a less than desirable dietary pattern, and the mean BMI was 34.2 (SD=9.2). Adults with a BMI of 30 or above are classified as obese.[41]

Table 2 describes the food shopping practices of women in our sample. Women used a median of two supermarkets (IQR=1.3-3.0) and two limited service outlets (the majority of which were fast food outlets; IQR=1.0-3.0) in the past month. Women reported shopping at these supermarkets a median of 4.6 times per month (IQR=2.0-8.7) and purchasing food from these limited service outlets a median of 3.6 times per month (IQR=1.5-8.1). The median distance from women's homes to the supermarkets where they shopped was 3.6 miles (IQR=2.3-5.3) and the median distance from women's homes to the limited service outlets they used was 2.9 miles (IQR=1.7-5.1). A small proportion of women used any supermarkets or limited service outlets women within their residential census tracts (20.6% and 22.2%, respectively); proportions were similar for the 1-mile road network buffer surrounding their homes.

What is the association between food access and BMI among low-income African American mothers in Atlanta, GA? Higher supermarket and convenience store density were associated with a higher BMI (Table 3). For supermarkets, associations were significant in the residential census tract (β=1.29, SE=0.65), 1-mile road network buffer (β=1.23, SE=0.62), and weighted activity space (β=1.29, SE=0.62). For convenience stores, associations were significant in the residential census tract (β=0.52, SE=0.25). All associations were attenuated and no longer significant after adjustment for the average density of 'unhealthy' or 'healthy' retailers, respectively, in the supermarket and convenience store models (Table 4).

Longer distance to the closest retailer was associated with a lower BMI for all outlet types except supermarkets (i.e. convenience stores, discount stores, and limited service outlets) (Table 3). For limited service outlets, associations were significant in the residential census tract and 1-mile road network buffer. For convenience stores, associations were significant in the census tract and unweighted activity space (i.e. activity points not weighted by visit frequency and duration), and for discount stores, associations were only significant in the 1-mile road network buffer. The degree to which the magnitude of association varied across environment type differed by food outlet category. For convenience stores, estimates ranged from -0.95 (SE=0.37) in the residential census tract to -3.38 (SE=1.70) in the unweighted activity space. For limited service outlets, estimates ranged from -0.62 (SE=0.28) in the 1-mile road network buffer to -0.84 (SE=0.26) in the residential census tract. Adjustment for the average distance to 'unhealthy' or 'healthy' retailers, respectively, did not substantively change the results (Table 4). However, the association between distance to the closest limited service outlet and BMI in the 1-mile road network buffer was no longer significant at $p<0.05$ (β=-0.66, SE=0.35, p=0.06), while the association between distance to the closest limited service outlet and BMI in the weighted activity space became significant at $p<.05$ (β=-0.82, SE=0.40)

What is the association between food access and dietary intake among low-income African American mothers in Atlanta, GA? Few features of the food environment were associated with dietary intake. Longer distance to the nearest discount store from the residential census tract centroid was associated with a less healthful dietary pattern (Table 5), however, this association was no longer significant after adjusting for distance to the nearest supermarket from the residential census tract centroid (Table 6).

What are the associations between food shopping practices and BMI/dietary intake among low-income African American mothers in Atlanta, GA? Several limited service outlet purchasing practices were associated with a less healthful dietary pattern (Table 7). For each additional unique limited service outlet used in the previous month, dietary score decreased by 0.60 points (SE=0.26), and for each additional trip to a limited service outlet in the previous month, dietary score decreased by 0.18 points (SE=0.08). Finally, for each additional dollar spent on eating out in the previous month, dietary score decreased by 0.02 points (SE=0.01). Supermarket shopping practices were not associated with dietary intake.

Neither supermarket nor limited service outlet shopping practices were associated with BMI, except for the use of any supermarkets within the residential census tract. Shopping at a supermarket within the residential census tract was associated with a lower BMI (β=-3.77, SE=1.77).

Discussion

This study used an activity space approach to examine how food access and food purchasing practices were associated with dietary intake and BMI among low-income African American women in Atlanta, GA. Contrary to our expectations, activity space measures did not help to clarify the pathways through which food environments may affect diet- and weight-related health. All observed associations would have been captured solely by examining the residential neighborhood environment, and some observed associations were only present in the residential neighborhood environment. Of the three dimensions of food access measured—availability, geographic proximity, and quality—proximity was the most consistently associated with BMI. In contrast, food purchasing practices, rather than food access, were the most salient predictors of dietary intake. Our results highlight the importance of examining both food environment exposure and use.

Although activity space measures provided a more comprehensive picture of the environments to which women were routinely exposed, residential neighborhoods appeared to be particularly salient areas of exposure. This finding is consistent with results from a study of low-income housing residents in New York City, which found that higher grocery store density in the residential neighborhood, but not the activity space, was associated with a lower BMI.[42] However, other studies have identified associations between food environments and dietary intake in activity spaces, but not residential neighborhoods,[23,43] and still others have found no associations with BMI in either residential neighborhoods or activity spaces.[44] Further, the studies that identified associations between activity space food environments and dietary intake/BMI were unable to address potential biases due to selective daily mobility given their use of GPS-defined activity spaces, which provide spatial and temporal data on locations visited, but typically do not provide information on the *type* of location visited. Additional research is needed to clarify differences between residential neighborhood and activity spaces measures of the food environment and their effect on health. The current body of literature is limited and direct comparisons are challenging due to the tremendous diversity in study populations and settings, as well as approaches to defining and measuring residential neighborhood and activity space environments, food access, and health outcomes.

Still, our findings may be explained by the fact that people spend a considerable amount of time in their residential neighborhoods, which often serve as a hub around which many activities of daily life revolve. As such, the food-related behaviors and norms that dominate in the residential neighborhood may be particularly influential in patterning diet- and weight-related behaviors and outcomes even for women who shop outside of their immediate residential neighborhoods.[16] The residential neighborhood may have been especially relevant for the women in our sample, nearly half of whom were unemployed and over one third of whom did not own a car. Kestens et al.'s finding that residential neighborhoods were more strongly associated with weight outcomes among women, while activity space environments were more strongly associated with weight outcomes among men,[25] suggests that gender differences in time use, place attachment, and mobility may benefit from further study. However, it is also possible that our findings reflect residual confounding due to neighborhood selection processes, or limitations of our approach to measuring activity space, which we discuss further below.

Acknowledging the multidimensionality of food access is critical to understanding how food environments affect health. Because the saliency of each dimension likely depends upon the reasons for using a particular outlet, it is unsurprising that being located farther away from "unhealthy" outlets, including convenience stores, discount stores, and limited service outlets, was associated with lower BMI, while there was no association between supermarket proximity and BMI. Convenience is one of the most frequently cited reasons for using limited service outlets and convenience stores (and one can imagine similar rationale for using discount stores, although these outlets have received less attention in the literature). If women are not located in close proximity to such outlets, they may be unlikely to go out of their way to find one. The use of convenience stores, discount stores, and limited services outlets may also be triggered by exposure to the outlet in the first place. There are various neurophysiological pathways through which obesogenic environments stimulate the desire to eat, and humans have limited capacity to control what are often automatic responses to environmental cues.[45] As such, further research is needed on the effectiveness of obesity prevention interventions that seek to reduce such environmental cues through regulation of the food environment (e.g. restricting the opening of new fast food outlets, replacing corner store inventories with healthier options, and reducing portion sizes).

In contrast to “unhealthy” outlets, supermarket choice is guided by numerous factors beyond convenience including affordability, family friendliness, acceptance of SNAP benefits, availability of culturally relevant foods, and more, and women are often willing to travel beyond their immediate environments to find a supermarket that fulfills these criteria.[29,30,46] Similar to other research conducted in low-income urban neighborhoods,[46,47] nearly every woman in our sample shopped at a supermarket, and approximately 80% of these women traveled outside of their residential census tracts to shop. Supermarket trips are also much more likely to be pre-planned. Encountering a supermarket in your residential neighborhood or routine activity space seems less likely to trigger an impromptu shopping trip than encountering a convenience store is to prompt an unplanned snack or drink purchase. Additional research is needed to further clarify how the most salient dimensions of access vary by outlet type. Interventions seeking to improve diet- and weight-related health by opening supermarkets or other healthy retailers in underserved areas implicitly assume that geographic proximity is a key determinant of use. The limited impact of such interventions may prompt us to think more holistically about what it means for a supermarket to be accessible.

Unlike proximity, food outlet density was not consistently associated with BMI or dietary intake. Understanding this finding requires consideration of the hypothesized pathways through which food outlet density affects diet- and weight-related behaviors. Do we believe that exposure to a higher density of unhealthy outlets triggers more cravings or leaves us more susceptible to marketing techniques? Is there a threshold at which higher densities no longer matter? For example, is exposure to seven fast food outlets over the course of a day less influential than exposure to ten? Given that most Americans (and nearly every woman in our sample) shop at a supermarket, do we believe that exposure to a higher density of supermarkets will increase shopping frequency or prompt the purchase of healthier items? Because our study was conducted in a large metropolitan area with many food outlets, it is possible that density was less salient because women were already exposed to a high number of unhealthy food outlets, and able to shop at supermarkets aligned with their preferences. In contrast, density may be more meaningful in a rural or less densely populated area where the range of densities differentiates areas with very few options from those with much greater availability.

It is worth noting that supermarket and chain density were positively associated with BMI prior to controlling for the density of other outlet types. While we may expect a higher density of convenience stores to provide greater access to unhealthy foods and result in a higher BMI, the positive association between supermarket density and BMI was unexpected (although ours is not the first study to observe such an association).[48] The overwhelming majority of women in our sample had unhealthy dietary patterns, and it is possible that supermarkets do not represent a source of healthy foods in this population. Other researchers have challenged the accepted classification of supermarkets as “healthy” as they contain a wide range of healthy and unhealthy food items. Closer examination of the foods women actually purchase while shopping, as well as in-store audits that capture product pricing, marketing, and placement, may help us better understand *when* and for *whom* supermarkets represent a source of healthy foods.

Still, after adjustment for the average density of “healthy” or “unhealthy” outlets, associations between supermarket and chain density and BMI were no longer significant. Because different types of food outlets are often located in close proximity to one another, it can be challenging to isolate the effects of one outlet type from another. In response, some researchers have suggested using *relative* measures of access that explicitly account for the diversity of outlets present in most food environments. For example, Clary et al.[49] found that a relative measure of access—percentage of healthy outlets—better predicted fruit and vegetable intake among Canadian men than absolute measures, such as supermarket or fast food outlet density. Further, when the authors used absolute measures controlling for overall outlet density, they encountered issues with collinearity. We confronted similar issues when attempting to control for the average density of all other outlet types, although these were largely resolved by controlling for “unhealthy” or “healthy” outlet density. That said, the relative measure of access we used, the mRFEI, was not associated with BMI or dietary intake.

In our examination of the associations between food purchasing practices and BMI/dietary intake, we found that using more unique limited service outlets, using limited service outlets more frequently, and spending more money eating out were associated with a less healthful dietary pattern. These findings are consistent with previous research showing that a greater frequency of fast food consumption is associated with poorer diet quality.[50-52] Interestingly, limited service purchasing practices were associated with dietary intake, but not BMI, while access to limited service outlets was associated with BMI, but not dietary intake. As described above, we reasoned that women who were located farther away from "unhealthy" outlets would be unlikely to go out of their way to find one, resulting in a healthier diet and lower BMI. We were therefore surprised that proximity to limited service outlets was not also associated with dietary intake. However, BMI is a more distal outcome than diet, and it is possible that food access is correlated with other features of the environment, such as green space or walkability (and thus, physical activity), that also affect BMI.[18] In other words, features of the food environment may be one element in a complex and synergistic network of environmental influences on BMI, rendering it more difficult to detect precise intermediary pathways.

In all likelihood, the majority of women in our sample were exposed to numerous limited service outlets, given their ubiquity in urban communities across the U.S. The question, therefore, becomes, why do some low-income women purchase fast food more frequently than others? As discussed above, part of the answer may lie in differential access (i.e. geographic proximity), but it is also likely that there are individual-level factors at play. People consume fast food despite knowledge of the health consequences because it is quick, convenient, inexpensive, and tastes good.[53-56] Some women may have more resources than others to overcome these incentives depending, for example, on their employment status, financial obligations, access to transportation, and the age of their children. From a population health perspective, it is most sensible to change the environments within which women make diet- and weight-related decisions, rather than seeking to change the decisions themselves, which are generally logical given individual constraints and available options.

Our study makes several important contributions to the small, but growing, body of literature comparing residential neighborhood and activity space measures of the food environment and their effect on diet- and weight-related health. Our study is one of very few to examine both dietary intake and BMI, and is further strengthened by our use of objectively measured BMI. Importantly, we explicitly addressed potential biases due to selective daily mobility, which few prior studies have been able to do. While our study was not designed, and is indeed unable, to demonstrate causality, accounting for selective daily mobility enables us to more confidently draw conclusions regarding the ways in which food access may influence dietary intake and BMI. An additional strength of our study was the examination of multiple dimensions of food access across multiple types of food outlets. Our results demonstrate that food access is a multidimensional construct, and that the saliency of each dimension may vary by outlet type. Understanding where, when, and how food access affects health, can strengthen the design and implementation of interventions seeking to make food environments more supportive of healthy eating. Further, by focusing our study on low-income African American women, we were able to highlight that important differences in food access and food shopping practices exist even within socio-demographically similar populations. This should serve as an important reminder that interventions cannot treat low-income or racial/ethnic minority communities as monolithic entities.

Despite these strengths, our study was subject to several important limitations. The use of a cross-sectional study design precludes us from drawing any conclusions regarding causality. Even still, we acknowledge that residential self-selection is a critical source of bias in studies examining the association between neighborhoods and health. Because one of the dominant forces sorting people into neighborhoods in the U.S. is residential segregation by race and class, we anticipate that neighborhood self-selection is less of an issue in our racially and socioeconomically homogeneous sample. Yet, while the homogeneity of our sample offers particular benefits, it also limits the generalizability of our study. Our approach to measuring activity space is also subject to several limitations. The VERITAS questionnaire collects self-reported data, which are subject to recall, social desirability, and other related biases. Further, VERITAS only assesses a subset of all locations visited by the participant, and does not capture the routes used to travel between locations. As a result, there may be additional areas of exposure relevant to dietary intake or BMI that were not assessed. Finally, the errors present in most secondary retail food environment data sources have been widely discussed, and may have resulted in some misclassification of our exposure measures. That said, government sources are among the most accurate (in the absence of primary data), and we subjected our data to a rigorous cleaning protocol.

Conclusion. Although activity space approaches can more accurately represent the environments to which people are exposed, they do not offer a magic bullet for understanding the complex ways in which people and places interact to affect health. Additional research is needed to understand how different approaches to defining and measuring activity space environments may affect results, and how the relative importance of residential neighborhoods and activity spaces may vary across populations and places. Further, food environment research requires continued consideration of the multidimensionality of food access. Proximity appeared to be the most salient dimension of access in our study, although results were only significant for “unhealthy” outlets. The saliency of each dimension likely depends upon motivations for using particular outlets, and interventions seeking to modify or regulate food access will likely need to attend to these differences. Examining the food environments to which people are exposed as well as their food purchasing practices may provide a more complete picture of the pathways through which food environments affect diet- and weight-related, and will likely provide the greatest insight into how food environments can be modified to be more supportive of healthy eating.

Table 3.1 Characteristics of low-income African American mothers in Atlanta, GA (n = 199)

	N or Mean	**% or SD**
Age (*mean, SD*)	32	6.7
Education (*n, %*)		
Less than high school	27	13.6
HS diploma or GED	85	42.7
Some college/technical school	54	27.1
Associate's degree or higher	33	16.6
Employment status (*n, %*)		
Full-time	74	37.2
Part-time	39	19.6
Unemployed, seeking employment	49	24.6
Unemployed, not seeking employment	37	18.6
Marital status (*n, %*)		
Currently married	22	11.1
Not married, living with partner	21	10.6
Never married	143	71.9
Divorced/separated/widowed	13	6.5
Household size (*mean, SD*)	4.1	1.6
Income (annual) (*n, %*)		
Less than $5,000	55	27.6
$5,000-$9,999	31	15.6
$10,000-$19,999	47	23.6
$20,000-$29,999	32	16.1
Greater than $30,000	34	17.1
Car ownership (*n, %*)		
Yes	126	63.3
No	73	36.7
SNAP benefits (*n, %*)		
Yes	157	78.9
No	42	21.1
Smoking status (*n, %*)		
Current	41	20.6
Former	23	11.6
Never	135	67.8
Dietary quality (0-54) (*mean, SD*)	28.5	5.2
BMI (*mean, SD*)	34.2	9.2

Table 3.2 Food shopping practices of low-income African American mothers in Atlanta, GA

	Supermarket (n=194)		Limited service outlet (n=167)	
	N or Median	% or IQR	N or Median	% or IQR
Unique outlets used (past month) (*median, IQR*)	2.0	1.3-3.0	2.0	1.0-3.0
Trip frequency (per month) (*median, IQR*)	4.6	2.0-8.7	3.6	1.5-8.1
Proximity from home to nearest utilized outlet (miles) (*median, IQR*)	3.6	2.3-5.3	2.9	1.7-5.1
Any outlets used in residential census tract (*n, %*)				
Yes	40.0	20.6	37.0	22.2
No	154.0	79.4	130.0	77.8
Any outlets used in 1-mile road network buffer (*n, %*)				
Yes	40.0	20.6	49.0	29.3
No	154.0	79.4	118.0	70.7
Amount spent grocery shopping (USD, past week) (*median, IQR*)	150.0	70.0-250.0	-	-
Amount spent eating out (USD, past week) (*median, IQR*)	-	-	22.0	7.0-50.0

Table 3.3 Associations between food access and BMI among low-income African American mothers in Atlanta, GA (n=199)

	Residential neighborhood [a]						**Activity space**					
	Census tract (ref)[b]			*Road network (1 mile)[c]*			*Activity space points, weighted (hours/month)*			*Activity space points, unweighted*		
	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value
Supermarkets												
Density (retailers/10 mi^2)	**1.29**	**0.65**	**0.05**	**1.23**	**0.62**	**0.05**	**1.29**	**0.62**	**0.04**	1.91	1.20	0.11
Proximity (distance to closest retailer) (miles)	0.05	0.22	0.82	-0.15	0.17	0.40	-0.01	0.21	0.96	0.63	0.48	0.19
Convenience stores												
Density (retailers/mi^2)	**0.52**	**0.25**	**0.03**	0.47	0.26	0.07	0.50	0.30	0.09	0.29	0.47	0.54
Proximity (distance to closest retailer) (miles)	**-0.95**	**0.37**	**0.01**	-0.65	0.37	0.08	-0.63	0.44	0.15	**-3.38**	**1.70**	**0.05**
Discount stores												
Density (retailers/10 mi^2)	0.10	0.47	0.84	0.20	0.46	0.66	0.07	0.47	0.89	0.34	1.12	0.76
Proximity (distance to closest retailer) (miles)	-0.10	0.24	0.69	**-0.49**	**0.20**	**0.01**	-0.45	0.27	0.09	-0.09	0.82	0.92
Limited service outlets												
Density (retailers/mi^2)	0.13	0.08	0.10	0.14	0.09	0.13	0.17	0.10	0.11	0.03	0.16	0.87
Proximity (distance to closest retailer) (miles)	**-0.84**	**0.26**	**0.001**	**-0.62**	**0.28**	**0.03**	-0.58	0.30	0.05	-1.54	1.17	0.19
mRFEI	-0.57	0.53	0.29	-0.23	0.49	0.63	-0.33	0.63	0.60	-1.01	1.04	0.33

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential census tract centroid to nearest outlet
[c] For proximity measures, this column displays distance from the residential address to nearest outlet
All models adjusted for: age, education, employment status, marital status, household size, annual income, car ownership, SNAP benefits, smoking status, and area-level median household income

Table 3.4 Associations between food access and BMI among low-income African American mothers in Atlanta, GA (n=199; additionally adjusted for other outlet types)

	Residential neighborhood [a]						Activity space					
	Census tract (ref)[b]			*Road network (1 mile)*[c]			*Activity space points, weighted (hours/month)*			*Activity space points, unweighted*		
	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value
Supermarkets												
Density (retailers/10 mi^2)	1.01	0.71	0.16	0.99	0.70	0.16	0.98	0.77	0.21	2.17	1.26	0.08
Proximity (distance to closest retailer) (miles)	0.31	0.23	0.18	0.09	0.21	0.66	0.30	0.28	0.28	0.77	0.51	0.13
Convenience stores												
Density (retailers/mi^2)	0.37	0.26	0.15	0.30	0.27	0.27	0.31	0.33	0.34	0.06	0.49	0.91
Proximity (distance to closest retailer) (miles)	**-1.21**	**0.40**	**0.002**	-0.62	0.44	0.16	-0.82	0.56	0.14	**-4.18**	**1.78**	**0.02**
Discount stores												
Density (retailers/10 mi^2)	-0.08	0.48	0.87	0.001	0.48	1.00	-0.05	0.47	0.91	0.81	1.08	0.46
Proximity (distance to closest retailer) (miles)	-0.13	0.26	0.62	**-0.49**	**0.25**	**0.05**	-0.57	0.35	0.10	-0.10	0.82	0.91
Limited service outlets												
Density (retailers/mi^2)	0.06	0.09	0.51	0.06	0.10	0.58	0.09	0.13	0.49	-0.10	0.17	0.57
Proximity (distance to closest retailer) (miles)	**-1.26**	**0.29**	**<.001**	-0.66	0.35	0.06	**-0.82**	**0.40**	**0.04**	-2.50	1.38	0.07
mRFEI	-0.57	0.53	0.29	-0.23	0.49	0.63	-0.33	0.63	0.60	-1.01	1.04	0.33

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential census tract centroid to nearest outlet
[c] For proximity measures, this column displays distance from the residential address to nearest outlet
All models adjusted for: age, education, employment status, marital status, household size, annual income, car ownership, SNAP benefits, smoking status, and area-level median household income

Supermarket models additionally adjusted for: average density of convenience stores, discount stores, and limited service outlets
Convenience store, discount store, and limited service outlet models additionally adjusted for: density of supermarkets

Table 3.5 Associations between food access and diet quality among low-income African American mothers in Atlanta, GA (n=199)

	Residential neighborhood [a]						**Activity space**					
	Census tract (ref) [b]			*Road network (1 mile)* [c]			*Activity space points, weighted (hours/month)*			*Activity space points, unweighted*		
	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value
Supermarkets												
Density (retailers/10 mi^2)	-0.06	0.29	0.83	-0.21	0.32	0.51	0.02	0.36	0.96	0.68	0.72	0.34
Proximity (distance to closest retailer) (miles)	0.01	0.11	0.95	-0.03	0.10	0.78	0.02	0.12	0.87	-0.11	0.36	0.76
Convenience stores												
Density (retailers/mi^2)	-0.004	0.17	0.98	-0.07	0.02	0.69	0.33	0.25	0.18	0.08	0.29	0.77
Proximity (distance to closest retailer) (miles)	-0.09	0.36	0.79	0.39	0.25	0.12	0.14	0.33	0.66	0.38	1.06	0.72
Discount stores												
Density (retailers/10 mi^2)	0.06	0.40	0.88	-0.08	0.24	0.74	-0.42	0.26	0.11	-0.002	0.41	1.00
Proximity (distance to closest retailer) (miles)	**-0.39**	**0.19**	**0.03**	0.06	0.14	0.67	-0.07	0.16	0.68	-0.07	0.32	0.82
Limited service outlets												
Density (retailers/mi^2)	-0.01	0.06	0.86	-0.02	0.06	0.71	0.04	0.06	0.54	-0.0002	0.09	1.00
Proximity (distance to closest retailer) (miles)	-0.04	0.18	0.85	0.20	0.16	0.22	0.07	0.20	0.73	-0.41	0.87	0.64
mRFEI	0.09	0.55	0.87	0.02	2.12	0.99	0.03	0.31	0.91	-0.22	0.51	0.67

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential census tract centroid to nearest outlet
[c] For proximity measures, this column displays distance from the residential address to nearest outlet
All models adjusted for: age, education, employment status, marital status, household size, annual income, car ownership, SNAP benefits, smoking status, and area-level median household income

Table 3.6 Associations between food access and diet quality among low-income African American mothers in Atlanta, GA (n=199; additionally adjusted for other outlet types)

	Residential neighborhood [a]						**Activity space**					
	Census tract (ref)[b]			*Road network (1 mile)[c]*			*Activity space points, weighted (hours/month)*			*Activity space points, unweighted*		
	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value	β (SE)	SE	p-value
Supermarkets												
Density (retailers/10 mi^2)	-0.05	0.38	0.90	-0.20	0.59	0.73	0.02	0.83	0.98	0.49	0.75	0.52
Proximity (distance to closest retailer) (miles)	0.06	0.13	0.64	-0.02	0.14	0.86	0.01	0.14	0.97	-0.10	0.37	0.78
Convenience stores												
Density (retailers/mi^2)	0.01	0.19	0.97	0.001	0.26	1.00	0.09	1.63	0.96	-0.01	0.31	0.98
Proximity (distance to closest retailer) (miles)	-0.10	0.32	0.74	0.39	0.28	0.17	0.13	0.44	0.76	0.56	1.06	0.60
Discount stores												
Density (retailers 10 mi^2)	0.07	0.34	0.84	-0.12	0.27	0.65	-0.09	0.45	0.84	0.13	0.46	0.77
Proximity (distance to closest retailer) (miles)	-0.14	0.17	0.42	0.02	0.31	0.94	-0.08	0.16	0.59	-0.07	0.32	0.83
Limited service outlets												
Density (retailers/mi^2)	-0.01	0.07	0.93	0.001	0.10	1.00	0.05	0.06	0.46	0.01	0.87	0.99
Proximity (distance to closest retailer) (miles)	-0.37	0.19	0.05	0.24	0.21	0.25	0.11	0.24	0.66	-0.35	0.86	0.69
mRFEI	0.09	0.55	0.87	0.02	2.12	0.99	0.03	0.31	0.91	-0.22	0.51	0.67

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential census tract centroid to nearest outlet
[c] For proximity measures, this column displays distance from the residential address to nearest outlet
All models adjusted for: age, education, employment status, marital status, household size, annual income, car ownership, SNAP benefits, smoking status, and area-level median household income

Supermarket models additionally adjusted for: average density of convenience stores, discount stores, and limited service outlets
Convenience store, discount store, and limited service outlet models additionally adjusted for: density of supermarkets

Table 3.7 Associations between food shopping practices, diet quality, and BMI among low-income African American mothers in Atlanta, GA (n=199)

	Diet quality			BMI		
	β (SE)	SE	p-value	β (SE)	SE	p-value
Supermarkets						
Number of unique supermarkets used (past month)	0.33	0.33	0.32	0.13	0.64	0.84
Supermarket trip frequency (past month) [a]	0.05	0.06	0.39	0.03	0.12	0.79
Average distance from home to utilized supermarkets (miles) [a]	0.33	0.32	0.30	-0.62	0.34	0.07
Amount spent grocery shopping (USD, past week) [a]	0.003	0.003	0.29	0.001	0.004	0.86
Any supermarkets used in tract [a]	0.01	0.87	0.99	**-3.77**	**1.77**	**0.03**
Any supermarkets used in RNB1 [a]	-0.45	1.04	0.67	-1.77	1.38	0.20
Limited service outlets						
Number of unique limited service outlets used (past month)	**-0.60**	**0.26**	**0.02**	-0.03	0.41	0.95
Limited service outlet trip frequency (past month) [b]	**-0.18**	**0.08**	**0.02**	0.07	0.14	0.61
Average distance from home to utilized limited service outlets (miles) [b]	0.09	0.09	0.31	-0.20	0.19	0.29
Amount spent eating out (USD, past week) [b]	**-0.02**	**0.01**	**0.04**	-0.01	0.02	0.71
Any limited service outlets used in tract [b]	0.25	0.86	0.77	-1.66	1.46	0.26
Any limited service outlets used in RNB1 [b]	-0.34	0.81	0.67	-0.09	1.40	0.95

[a] Practices only examined among women who reported shopping at a supermarket in the past month (n=194)

[b] Practices only examined among women who reported purchasing food at a limited service outlet in the past month (n=167)

All models adjusted for: age, education, employment status, marital status, household size, annual income, car ownership, SNAP benefits, smoking status, and area-level median household income

References

1. Sallis JF, Owen N, Fisher E. Ecological Models of Health Behavior. In: Glanz K, Rimer B, Viswanath K, eds. *Health Behavior and Health Education: Theory, Research, and Practice.* 4th ed. California: Jossey-Bass; 2008:465-482.
2. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med.* 2009;36(1):74-81.
3. Baker EA, Schootman M, Barnidge E, Kelly C. The Role of Race and Poverty in Access to Foods That Enable Individuals to Adhere to Dietary Guidelines. *Preventing chronic disease.* 2006;3(3):A76.
4. Bower KM, Thorpe Jr RJ, Rohde C, Gaskin DJ. The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Preventive Medicine.* 2014;58:33-39.
5. Kwate NOA. Fried chicken and fresh apples: Racial segregation as a fundamental cause of fast food density in black neighborhoods. *Health & Place.* 2008;14(1):32-44.
6. Ford PB, Dzewaltowski DA. Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses. *Nutr Rev.* 2008;66(4):216-228.
7. Sallis JF, Glanz K. Physical activity and food environments: solutions to the obesity epidemic. *Milbank Q.* 2009;87(1):123-154.
8. Gordon-Larsen P, Nelson MC, Page P, Popkin BM. Inequality in the Built Environment Underlies Key Health Disparities in Physical Activity and Obesity. *Pediatrics.* 2006;117(2):417-424.
9. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built Environments and Obesity in Disadvantaged Populations. *Epidemiologic Reviews.* 2009;31(1):7-20.
10. Black C, Moon G, Baird J. Dietary inequalities: What is the evidence for the effect of the neighbourhood food environment? *Health & Place.* 2014;27:229-242.

11. Wilkins E, Radley D, Morris M, et al. A systematic review employing the GeoFERN framework to examine methods, reporting quality and associations between the retail food environment and obesity. *Health & Place.* 2019;57:186-199.

12. Bivoltsis A, Cervigni E, Trapp G, Knuiman M, Hooper P, Ambrosini GL. Food environments and dietary intakes among adults: does the type of spatial exposure measurement matter? A systematic review. *International Journal of Health Geographics.* 2018;17(1):19.

13. Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CAM. The relationship of the local food environment with obesity: A systematic review of methods, study quality, and results. *Obesity.* 2015;23(7):1331-1344.

14. Kwan M-P. The Uncertain Geographic Context Problem. *Annals of the Association of American Geographers.* 2012;102(5):958-968.

15. Cummins S. Commentary: Investigating neighbourhood effects on health—avoiding the 'Local Trap'. *International Journal of Epidemiology.* 2007;36(2):355-357.

16. Clary C, Matthews SA, Kestens Y. Between exposure, access and use: Reconsidering foodscape influences on dietary behaviours. *Health & Place.* 2017;44:1-7.

17. Lucan SC. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *J Acad Nutr Diet.* 2015;115(2):205-212.

18. Cummins S, Clary C, Shareck M. Enduring challenges in estimating the effect of the food environment on obesity. *The American journal of clinical nutrition.* 2017;106(2):445-446.

19. Chen X, Kwan M-P. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. *American journal of public health.* 2015;105(9):1734-1737.

20. Crawford TW, Jilcott Pitts SB, McGuirt JT, Keyserling TC, Ammerman AS. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health & Place.* 2014;30:215-225.

21. Kestens Y, Lebel A, Daniel M, Thériault M, Pampalon R. Using experienced activity spaces to measure foodscape exposure. *Health & Place.* 2010;16(6):1094-1103.

22. Matthews SA, Yang T-C. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist.* 2013.

23. Zenk SN, Schulz AJ, Matthews SA. Activity space environment and eating and physical activity behaviors: A pilot study. *Health and Place.* 2011;17:1150 - 1161.

24. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine.* 2012;43(4):440-450.

25. Kestens Y, Lebel A, Chaix B, et al. Association between Activity Space Exposure to Food Establishments and Individual Risk of Overweight. *PLoS ONE.* 2012;7(8):e41418.

26. Brown DR, Brewster LG. The food environment is a complex social network. *Social Science & Medicine.* 2015;133:202-204.

27. Cooksey-Stowers K, Schwartz MB, Brownell KD. Food Swamps Predict Obesity Rates Better Than Food Deserts in the United States. *International Journal of Environmental Research and Public Health.* 2017;14(11):1366.

28. Cannuscio CC, Hillier A, Karpyn A, Glanz K. The social dynamics of healthy food shopping and store choice in an urban environment. *Social Science & Medicine.* 2014;122:13-20.

29. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and Supermarket Access: Proximity or Price? *American journal of public health.* 2012;102(8):e74-e80.

30. DiSantis KI, Hillier A, Holaday R, Kumanyika S. Why do you shop there? A mixed methods study mapping household food shopping patterns onto weekly routines of black women. *The international journal of behavioral nutrition and physical activity.* 2016;13(1):11.

31. Woodruff RC, Raskind IG, Harris DM, et al. The dietary impact of introducing new retailers of fruits and vegetables into a community: results from a systematic review. *Public Health Nutr.* 2017:1-11.

32. Freedman DA, Bell BA, Clark JK, et al. Socioecological Path Analytic Model of Diet Quality among Residents in Two Urban Food Deserts. *Journal of the Academy of Nutrition and Dietetics.* 2019.

33. Hager ER, Cockerham A, O'Reilly N, et al. Food swamps and food deserts in Baltimore City, MD, USA: associations with dietary behaviours among urban adolescent girls. *Public Health Nutr.* 2016:1-10.

34. Hardcastle SJ, Blake N. Influences underlying family food choices in mothers from an economically disadvantaged community. *Eat Behav.* 2016;20:1-8.

35. Bisogni CA, Connors M, Devine CM, Sobal J. Who we are and how we eat: a qualitative study of identities in food choice. *J Nutr Educ Behav.* 2002;34.

36. Jones KK, Zenk SN, Tarlov E, Powell LM, Matthews SA, Horoi I. A step-by-step approach to improve data quality when using commercial business lists to characterize retail food environments. *BMC Res Notes.* 2017;10(1):35.

37. CDC. Census Tract Level State Maps of the Modified Retail Food Environment Index (mRFEI). In.

38. Green SH, Glanz K. Development of the Perceived Nutrition Environment Measures Survey. *Am J Prev Med.* 2015;49(1):50-61.

39. Jilcott SB, Keyserling TC, Samuel-Hodge CD, Johnston LF, Gross MD, Ammerman AS. Validation of a brief dietary assessment to guide counseling for cardiovascular disease risk reduction in an underserved population. *J Am Diet Assoc.* 2007;107(2):246-255.

40. Ammerman AS, Haines PS, DeVellis RF, et al. A brief dietary assessment to guide cholesterol reduction in low-income individuals: design and validation. *J Am Diet Assoc.* 1991;91(11):1385-1390.

41. Division of Nutrition PA, and Obesity, National Center for Chronic Disease Prevention and Health Promotion,. About Adult BMI. Centers for Disease Control and Prevention. Published 2015. Accessed March 18, 2017.

42. Tamura K, Elbel B, Athens JK, et al. Assessments of residential and global positioning system activity space for food environments, body mass index and blood pressure among low-income housing residents in New York City. *Geospatial health.* 2018;13(2).

43. Shearer C, Rainham D, Blanchard C, Dummer T, Lyons R, Kirk S. Measuring food availability and accessibility among adolescents: Moving beyond the neighbourhood boundary. *Social Science & Medicine.* 2015;133:322-330.

44. Burgoine T, Jones AP, Namenek Brouwer RJ, Benjamin Neelon SE. Associations between BMI and home, school and route environmental exposures estimated using GPS and GIS: do we see evidence of selective daily mobility bias in children? *International Journal of Health Geographics.* 2015;14(1):8.

45. Cohen DA. Neurophysiological Pathways to Obesity: Below Awareness and Beyond Individual Control. *Diabetes.* 2008;57(7):1768-1773.

46. Hillier A, Cannuscio CC, Karpyn A, McLaughlin J, Chilton M, Glanz K. How Far Do Low-Income Parents Travel to Shop for Food? Empirical Evidence from Two Urban Neighborhoods. *Urban Geography.* 2011;32(5):712-729.

47. Dubowitz T, Zenk SN, Ghosh-Dastidar B, et al. Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutr.* 2015;18(12):2220-2230.

48. Wang MC, Kim S, Gonzalez AA, Macleod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. *J Epidemiol Community Health.* 2007;61.

49. Clary CM, Ramos Y, Shareck M, Kestens Y. Should we use absolute or relative measures when assessing foodscape exposure in relation to fruit and vegetable intake? Evidence from a wide-scale Canadian study. *Preventive Medicine.* 2015;71:83-87.

50. Satia JA, Galanko JA, Siega-Riz AM. Eating at fast-food restaurants is associated with dietary intake, demographic, psychosocial and behavioural factors among African Americans in North Carolina. *Public Health Nutrition.* 2004;7(8):1089-1096.

51. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR, Franco M. Fast-Food Consumption, Diet Quality, and Neighborhood Exposure to Fast Food: The Multi-Ethnic Study of Atherosclerosis. *American Journal of Epidemiology.* 2009;170(1):29-36.

52. Bowman SA, Vinyard BT. Fast Food Consumption of U.S. Adults: Impact on Energy and Nutrient Intakes and Overweight Status. *Journal of the American College of Nutrition.* 2004;23(2):163-168.

53. Rydell SA, Harnack LJ, Oakes JM, Story M, Jeffery RW, French SA. Why eat at fast-food restaurants: reported reasons among frequent consumers. *J Am Diet Assoc.* 2008;108(12):2066-2070.

54. Raskind IG, Woodruff RC, Ballard D, et al. Decision-making processes shaping the home food environments of young adult women with and without children. *Appetite.* 2017;113:124-133.

55. Garza KB, Ding M, Owensby JK, Zizza CA. Impulsivity and Fast-Food Consumption: A Cross-Sectional Study among Working Adults. *Journal of the Academy of Nutrition and Dietetics.* 2016;116(1):61-68.

56. Anderson B, Rafferty AP, Lyon-Callo S, Fussman C, Imes G. Fast-food consumption and obesity among Michigan adults. *Preventing chronic disease.* 2011;8(4):A71-A71.

Chapter 4: Putting food insecurity into place: Associations between the community food environment, food shopping practices, and food insecurity among low-income African American women in Atlanta, GA

Abstract

Background: Food insecurity is a complex social and economic condition influenced by factors at multiple levels of the social ecology. Yet, few studies have attempted to put food security "into place" by examining associations with features of the environments in which people live.

Objective: In a sample of low-income African American women in Atlanta, GA, we examined whether: 1) food secure and food insecure women are exposed to different food environments, and 2) food shopping practices differ by food security status.

Methods: We recruited women between the ages of 18-44 from two safety-net care clinics (n=199). To quantify the environments to which women were exposed, we used a web-based questionnaire to geolocate their residential address and other locations routinely visited. Retail food outlet data were obtained from the Georgia Departments of Public Health (GDPH) and Agriculture (GDA). We assessed three dimensions of objective food access: density, geographic proximity, and quality, as well as self-reported perceived access to healthy and unhealthy foods. Food shopping practices were self-reported. Food security status was assessed using the U.S. Department of Agriculture's 18-item Household Food Security Survey Module. We used logistic regression to estimate adjusted associations between food security status and 1) objective food access, 2) perceived food access, and 3) food shopping practices.

Results: Approximately half of the women in the sample were food insecure (50.8%). Objective and perceived food access differed minimally by food security status. However, compared to food secure women, food insecure women were exposed to healthier food environments beyond their residential neighborhoods (OR=1.46, 95% CI: 0.94-2.26, p=0.09). Food shopping practices were also similar for food secure and food insecure women, although food insecure women more frequently shopped at discount stores (OR=1.11, 95% CI: 1.00-1.23, p=0.06).

Conclusions: Interventions seeking to improve community food environments and food shopping practices may not require special tailoring by food security status. Still, results suggest that food insecure women may choose to visit environments that offer a greater number or diversity of healthy options than their residential neighborhoods. Future research may wish to explore the conditions under which food insecure women travel outside of their residential environments to access food, and the potential hidden costs of doing so (e.g. time and transportation).

Introduction

In 2017, 11.8% of U.S. households experienced food insecurity, defined by the U.S. Department of Agriculture as “a household-level economic and social condition of limited or uncertain access to adequate food.”[1] As it is measured in the U.S., the experience of food insecurity can range in severity from diminished diet quality, variety, or desirability to actual reductions in food intake and disrupted eating patterns.[1] Food insecurity has been associated with numerous health conditions, including obesity, diabetes, hypertension, depression, and poor oral health.[2-4] Importantly, significant socio-demographic disparities exist: households with children, households headed by a single parent (particularly mothers), non-Hispanic Black households, and Hispanic households have a substantially higher prevalence of food insecurity compared to the national average.[1]

Although food insecurity is closely related to poverty, the two are not synonymous. In 2017, nearly two-thirds of households living below the federal poverty line did not experience food insecurity, raising important questions regarding the role of other risk factors.[1] Individual- and interpersonal-level factors such as adverse childhood experiences,[5] living with a disability,[6] experiencing intimate partner violence,[7] substance use,[8] and limited social support[9,10] have been associated with a greater risk of experiencing food insecurity. However, factors at higher levels of the social ecology have received little attention.

A limited number of studies have attempted to put food security “into place” by examining associations with features of the social, economic, food, and policy environments in which people live.[8,11,12] Existing studies have found that adults in Philadelphia who reported better access to fruits and vegetables were less likely to be food insecure,[13] and food insecure families in South Carolina had lower odds of perceived access to healthy and affordable foods.[14] However, among low-income families in Toronto, there was no association between proximity to supermarkets or perceived food access and food security status.[15] Fewer studies have examined how food insecure households navigate or interact with their food environments. Among low-income African American families in Baltimore, the types of outlets where families purchased food were not associated with their food security status,[16] while traveling a farther distance to the store where most groceries were purchased was associated with higher odds of adult food insecurity among Mexican-origin families along the Texas-Mexico border.[17]

The ways in which the food environment may exacerbate or mitigate food insecurity are likely complex. Many low-income and communities of color have poorer access to affordable healthy foods and abundant access to inexpensive unhealthy foods.[18-20] For a family already at-risk of experiencing food insecurity, this may compound existing challenges to maintaining an adequate food supply. For example, it is generally less expensive to purchase grocery items and prepare them for at-home consumption than it is to purchase prepared meals.[21] However, if you have limited access to a supermarket, as well as transportation or time constraints, you may opt to purchase prepared foods even if the result is overall higher food expenditures. Similarly, travelling a greater distance to reach a supermarket, particularly in the absence of a car, will likely result in transportation costs that deplete already limited food budgets, while opting to purchase staple items at nearby stores, such as small grocers or corner stores where prices are typically higher, will have the same effect.

The reverse scenario is also possible—a person's food security status may affect the food environments to which they are exposed. The places a person chooses to go likely depends upon a variety of factors, including their available resources.[22] A food insecure family may seek out particular retailers or other sources of food that maximize their ability to meet their household needs. Resource limitations may also *constrain* the spatial behavior of food insecure families, limiting them to particular environments or places. Food environment research typically relies on residential neighborhood boundaries to delineate the environments to which people are exposed, despite the reality that people experience—by choice and otherwise—a multiplicity of environments as they move through their daily lives.[23,24] In response, researchers have begun to advocate for the use of 'activity space' approaches that account for the full collection of places people routinely visit.[22,25,26]

Activity space approaches not only provide a more accurate representation of the environments to which people are exposed, but allow for comparisons to be made between residential and activity space environments. The degree to which these environments differ may offer insight into the ways in which people navigate and interact with their food environments. For example, if we believe that food insecure families are more limited in their ability to travel beyond their local environments, we may expect their residential and activity space food environments to be more similar than those of food secure families. In contrast, if we believe that food insecure families are exposed to poorer local food environments, we may expect them to seek food in other locations, resulting in greater differences between their residential and activity space environments compared to food secure families. While a small but growing number of studies have used activity space approaches to examine food environments,[25-29] no studies have done so in relation to food insecurity.

The present study represents the first step in an attempt to untangle the complex relationship between food environments and food insecurity. We examine the residential and activity space food environments and food shopping practices of food secure and food insecure low-income African American mothers living in Atlanta, GA. We focus on this population given their substantially higher risk for experiencing food insecurity. We explore the following research questions:

1. Are food secure and food insecure women exposed to different food environments?
    a. Do differences between residential and activity space environments vary by food security status?
2. Are the food shopping practices of food secure and food insecure women different? If so, might practices vary because food secure and food insecure women are exposed to different environments, or because they use the same environment in different ways?

Methods

Population and setting. We recruited participants from two safety net health care clinics in Atlanta, GA, USA. Women were eligible for participation if they were: between the ages of 18-44, African American, living with at least one child under the age of 18, and able to comprehend written and spoken English. Women confirmed as currently pregnant were excluded due to potential differences in spatial behavior, mobility, and food shopping practices. Each study visit lasted for approximately 45 minutes to one hour, and women were compensated $20 in cash for their time. The Emory University Institutional Review Board and the Grady Health Systems Research Oversight Committee approved all study protocols.

Data sources. ***Activity space data***. We used an adapted version of the Visualization and Evaluation of Routine Itineraries, Travel destinations, and Activity Spaces (VERITAS) questionnaire to collect activity space data.[30] The interviewer-administered questionnaire asks participants to report the name and address of: 1) key anchor points in their daily routine (e.g. home, work, school), and 2) other locations visited at least once in the previous month. Specifically, participants are asked about 21 different types of locations they may have visited, including food-seeking locations (e.g. supermarkets, restaurants), commerce or service locations (e.g. hair or nail salons), social locations (e.g. movies, plays, concerts), family-related locations (e.g. family member's homes, taking children to school), and health services locations (e.g. doctor's office, pharmacy). For several location types (e.g. health services locations), participants report any visits made during the previous year. Participants also report contextual information about each location visited, including visit frequency, visit duration, and the typical mode of transportation used to reach the location. Participants can report up to five locations for each of the 21 location types. The VERITAS questionnaire is embedded with Google Maps functionality, which allows the interviewer to search and input each location directly onto the map.

Retail food environment data. We obtained the names and addresses of retail food outlets located in our study area from the Georgia Departments of Public Health (GDPH) and Agriculture (GDA). We defined our study area as the Atlanta Regional Commission's (ARC) 10-county area, which includes Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry, and Rockdale counties. We geocoded the retail food outlets using Google Maps' Geocoding API, and achieved a 99.9% match rate. We then implemented an in-depth data cleaning protocol, which included three primary steps: 1) removing outlets deemed ineligible for inclusion (e.g. not open to the public, no permanent retail location, or not primarily visited for the purpose of obtaining food), 2) removing duplicate records, and 3) classifying outlets into one of six categories: supermarkets, grocery stores, convenience stores/pharmacies, discount general merchandise stores (e.g. dollar stores), limited service outlets (e.g. fast food, coffee shops, ice cream parlors), and full service restaurants. In the present study, we chose not to examine grocery stores or full service restaurants as we could not establish a strong theoretical justification for treating them as “healthy” or “unhealthy” outlets, a distinction we use when defining food access. Additional detail on our data cleaning protocol has been reported elsewhere (see Chapter 2).

Food security status, perceived food environment, food shopping practices, and socio-demographic characteristics. We collected data on food security status, the perceived food environment, food shopping practices, and participant socio-demographic characteristics using a web-based survey administered immediately prior to the activity space questionnaire.

Area-level median household income. We obtained census block group-level median household income data from the 2017 American Community Survey.

Measures. ***Defining residential neighborhood and activity space food environments***. We defined the residential neighborhood as the 1-mile road network buffer surrounding the participant’s residential address. We defined the activity space environment in two ways: 1) the set of participant-reported activity locations, and 2) the set of participant-reported activity locations weighted by the frequency and duration of each visit (hours per month). Because the VERITAS questionnaire does not ask participants to report the number of hours spent per day at their home address, we imputed this value using gender- and employment-status specific estimates from the American Time Use Survey (11.7 and 13.5 hours per day for women who are employed and unemployed, respectively).[31]

Objective food access. We assessed three dimensions of food access: density, geographic proximity, and quality. Density and geographic proximity were calculated separately for each outlet type. We used kernel density estimation (KDE), with a 1-mile bandwidth, to construct a continuous surface of outlet density per square mile. We then placed the participant’s residential neighborhood (i.e. 1-mile road network buffer) and activity locations on the continuous surface in order to determine the average outlet density in their residential neighborhood and activity space environments. For the 1-mile road network buffer, we extracted the average outlet density within the polygon, and for the activity locations (unweighted and weighted), we extracted the outlet density at each point and then calculated the average for the set of points.

Geographic proximity was defined as the road network distance to the closest outlet. For the residential neighborhood, we calculated distance from the residential address to the closest outlet, and for the activity space environments (unweighted and weighted), we calculated the distance from each activity location to the closest outlet and then calculated the average for the set of points.

We measured quality using the Centers for Disease Control and Prevention's (CDC) modified retail food environment index (mRFEI).[32] The mRFEI is calculated by the dividing the number of 'healthy' retailers in a given area by the total number of 'healthy' and 'unhealthy' retailers in the same area. For our analyses, we categorized supermarkets as 'healthy' retailers and convenience store/pharmacies, discount general merchandise stores, and limited service outlets as 'unhealthy' retailers. The KDE approach described above was used to calculate the mRFEI for the residential neighborhood and activity space environments.

Access measures in the activity space environments were calculated with attention to the issue of selective daily mobility bias.[30] This form of bias can arise when there are unmeasured factors associated with the places a person chooses to go as well as the health behavior or outcome of interest. For example, if we believe that exposure to a higher density of supermarkets is associated with lower odds of food insecurity, we want to ensure that any observed associations are not driven by an unmeasured factor that makes food insecure women more likely to shop at, and thus more likely to be exposed to, supermarkets. This can be done by excluding activity space locations that match the exposure in question when calculating access. Thus, in the above example, we would exclude supermarkets visited by the participant when calculating access to supermarkets in her activity space. We calculated all measures of objective food access in the activity space using this approach.

Perceived food access. We measured the perceived food environment using two composite items from the Perceived Nutrition Environment Measures Survey (NEMS-P): store availability of healthy food choices and restaurant availability of healthy options.[33] The store availability of healthy food choices composite item is comprised of six items (e.g. "*It is easy to buy fresh fruits and vegetables in my neighborhood*" and "*The fresh produce in my neighborhood is of high quality*"). The restaurant availability of healthy options composite item is comprised of three items (e.g. "*There are many healthy menu options at the restaurants in my neighborhood*"). The original NEMS-P composite item refers to the restaurant that participants go to most often. We adapted the item to refer to restaurants available in the participant's neighborhood in order to better align with the store availability of healthy food choices composite item and our study goals.

Responses for both composite items were measured on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree". All items were coded so that a higher score reflects higher perceived availability of healthy options. In our sample, internal consistency was good for both composite items (Cronbach's alpha = 0.90 for store availability of healthy food choices and Cronbach's alpha = 0.81 for restaurant availability of healthy options). Good test-retest reliability has also been demonstrated, with Kappa coefficients greater than 0.60 for composite items.[33]

Food shopping practices. For each outlet type, activity space data were used to calculate whether or not the participant used the outlet type in the past month (yes; no), the number of unique outlets used in the past month (continuous), trip frequency in the past month (continuous), average distance from home to the utilized outlets (continuous), and whether or not the participant used any outlets within the boundaries of their residential neighborhood (yes; no). Participants also reported the dollar amount spent on groceries and eating out, respectively, in the past week; we treated both variables as continuous.

Food security status. Food security status was measured with the United States Department of Agriculture's (USDA) 18-item Household Food Security Survey Module (HFSSM).[34] The HFSSM has been used to monitor the national prevalence of food insecurity since 1995, and extensive testing has demonstrated its validity and reliability across diverse populations. The HFSSM includes 10 questions pertaining to the food security status of adults in the household and eight questions pertaining to the food security status of children in the household. Adult-referenced questions range in severity from "*'We* *worried whether our food would run out before we got money to buy more.' Was that often true, sometimes true, or never true for your household in the last 12 months?*" to "*In the last 12 months, did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?*" Child-referenced questions range in severity from "*'We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food.' Was that often, sometimes, or never true for your household in the last 12 months?*" to "*In the last 12 months did your child ever not eat for a whole day because there wasn't enough money for food.*" Households with children receive a raw score ranging from zero to 18. Households with a raw score of zero are classified as having "high food security", households with a raw score of one to two are classified as having "marginal food security", households with a raw score of three to seven are classified as having "low food security", and households with a raw score of eight or higher are classified as having "very low food security". Households classified as having "high food security" or "marginal food security" are considered "food secure" and households classified as having "low food security" or "very low food security" are considered "food insecure".

Covariates. We examined the following covariates as candidates for inclusion in adjusted analyses: age (continuous); education (less than high school; high school diploma or GED; some college or technical school; Associate's degree or higher); employment status (full-time employment; part-time employment; unemployed, but seeking employment; unemployed, and not seeking employment); marital status (currently married; not married, but living with a partner; never married; divorced, widowed, or separated); household size (continuous); annual income (less than $5,000; $5,000-$9,999; $10,000-$19,999; $20,000-$29,000, greater than or equal to $30,000); car ownership (yes; no); receipt of SNAP benefits (yes; no); and area-level median household income (continuous). As described above, we used KDE to construct a continuous surface of the spatially varying median household income across the study area, and then extracted the average value within the 1-mile road network buffer.

Analysis. Four participants were excluded as a result of incomplete data or data quality concerns. Our final analytic sample size was 199. Further, because two participants declined to share their residential address, all analyses including the residential neighborhood (i.e. 1-mile road network buffer) have a sample size of 197. We used median and modal imputation to address the small amount of missing data on control variables. We imputed the modal vale of ‘less than $5,000’ for the one participant who did not report her annual income. For the eight activity locations (out of 3,184) missing information on visit frequency and/or duration, we imputed median values specific to the type of location (e.g. doctor’s office, supermarket, family member’s home).

We examined bivariate associations between food security status and a) socio-demographic characteristics, b) objective food access, c) perceived food access, and d) food shopping practices. We also examined bivariate associations between food environment type (i.e. residential neighborhood, unweighted activity space points, and weighted activity space points) and each dimension of objective food access (i.e. density, geographic proximity, and quality). As appropriate, we used two independent sample t-tests, chi-square tests, Fisher’s exact tests, and Wilcoxon-Mann-Whitney tests to determine the significance of bivariate associations at $p<0.10$ given the exploratory nature of the study.

We used logistic regression to estimate adjusted associations between food security status and a) objective food access, b) perceived food access, and c) food shopping practices. All models were adjusted for variables significantly associated with food security status in bivariate analyses, including age, marital status, annual income, and car ownership. We did not adjust for the full set of covariates described above because we believe that the relationships between food security status and food access/food shopping practices are likely bidirectional, and it was not our goal to estimate the least biased causal effects. Rather, we were interested in adjusting for several covariates that may be more prevalent among food insecure women and may also be associated with food access/food shopping practices, in order to enhance our understanding of any observed associations.

For models estimating the association between food security status and objective food access, we also adjusted for the average density or geographic proximity of ‘unhealthy’ outlets for the supermarket models, and the average density or geographic proximity of ‘healthy’ outlets for the convenience store/pharmacy, discount general merchandise store, and limited service outlet models. We included this additional control variable in an attempt to address the possibility that ‘healthy’ and ‘unhealthy’ retail food outlets are located next to one another. We found no evidence of model collinearity using a Variance Inflation Factor (VIF) cut-off of greater than or equal to four. As a sensitivity analysis, we re-estimated all models using generalized estimating equations (GEE) to control for the correlation of women within residential census tracts. There were no consistent or substantial differences in the results.

We calculated road network distances using ArcGIS Network Analyst (Version 10.6. Redlands, California: Environmental Systems Research Institute, Inc.). All other analyses were conducted in R version 3.5.1.

Results

Women were 32 years old (SD=6.7), on average (Table 1). Over half had obtained a high school diploma or less, and over half were employed, while another quarter were actively seeking employment. Nearly three-quarters had never been married, and the average household was comprised of four people. Approximately two-thirds of women earned less than $20,000 per year, nearly two-thirds owned a car, and nearly 80% received SNAP benefits. Approximately half of the women in the sample were food insecure (50.8%). Food insecure women were older, less frequently married or living with a partner and more often divorced, separated, or widowed, had lower annual incomes, and less frequently owned a car.

Food access in the objective and perceived food environment. Table 2 summarizes objective and perceived food access, and tests hypotheses of equivalence between residential and activity space environments and between food secure and food insecure women. Food access in the objective and perceived food environments differed by food security status. Almost all of these differences were observed in the residential neighborhood environment; there were few differences between the activity space food environments of food secure and food insecure women. In their residential neighborhoods, food insecure women were located in closer proximity to convenience stores, discount stores, and limited service outlets compared to food secure women. For example, the nearest convenience store was located

0.45 miles (SD=0.35) from home for food insecure women, and 0.59 miles (SD=0.51) from home for food secure women. There were no significant differences in food outlet density or mRFEI by food security status. Regarding the perceived food environment, food insecure women reported poorer availability of healthy options at the restaurants in their neighborhood (M=2.42, SD=1.25 for food secure women vs. M=2.07, SD=1.20 for food insecure women).

While food access differed between the residential neighborhood and activity space environments, the magnitude of these differences varied minimally by food security status. Compared to the residential neighborhood, activity space food environments generally contained a higher density of food outlets. This pattern was seen for both food secure and food insecure women, and for all outlet types except discount general merchandise stores, whose density did not vary between residential neighborhood and activity space environments. The largest differences were observed between the residential neighborhood and the unweighted activity space environment. For example, there were 0.17 supermarkets per square mile (SD=0.12) in the residential neighborhood and 0.25 supermarkets per square mile (SD=0.08) in the unweighted activity space for both food secure and food insecure women.
Compared to the residential neighborhood, activity space points were located in closer proximity to food outlets. Again, this pattern was observed regardless of food security status, and the differences were greatest between the residential neighborhood and the unweighted activity space environment. For example, for food secure women, the closest limited service outlet was located 0.75 miles (SD=0.67) from their home, but an average of 0.29 miles (SD=0.12) from their activity space points. There were minimal differences in the mRFEI between the residential neighborhood and activity space environments. For food insecure women, the unweighted activity space environment was slightly healthier than the residential neighborhood (M=2.37, SD=0.81 for unweighted activity space vs. M=2.16, SD=1.46 for residential neighborhood). This pattern was not observed for food secure women.

In adjusted models (Table 3), all differences in food access by food security status were attenuated and no longer statistically significant. However, in the unweighted activity space environment, there were several differences in objective food access that were not observed in the unadjusted models.

In the unweighted activity space, a higher density of convenience stores and limited service outlets were associated with lower odds of food security (although effect sizes were very close to null), and a healthier food environment was associated with higher odds of food insecurity (OR=1.46, 95% CI: 0.94-2.26, p=0.09).

Food shopping practices. There were few statistically significant differences in the food shopping practices of food secure and food insecure women (Table 4). Notably, food insecure women were more likely to have shopped at a discount store in the past month (38.6% vs. 26.5%). Although there was a statistically significant difference between the number of unique convenience stores used in the past month, the median number of stores used was the same for food secure and food insecure women, likely due to the skewed distribution of the variable. Despite the lack of statistically significant differences, descriptively, there were several notable differences in food shopping practices by food security status. Food insecure women were more likely to use supermarkets (23.2% vs. 17.9%) and limited service outlets (33.3% vs. 25.3%) within their residential neighborhoods, made more trips to convenience stores (median=21.7 trips vs. 11.2 trips) and discount stores (median=8.7 trips vs. 4.3 trips) in the past month, and spent slightly less on groceries (median=$125 vs. $150) and eating out in the previous week (median=$20 vs. $24).

In adjusted analyses (Table 5), differences in food shopping practices were no longer significant, with one exception: each additional trip to a discount store was associated with 11% higher odds of food insecurity (95% CI: 1.00-1.23, p=0.06).

Discussion

In this study, we examined whether food access and food shopping practices differed by food security status among low-income African American mothers in Atlanta, GA. Food insecurity was highly prevalent in our sample; over 50% of women reported experiencing food insecurity in the past year. Overall, objective and perceived food access differed minimally by food security status. However, food insecure women were exposed to healthier activity space food environments, suggesting that they may choose to visit environments that offer a greater number or diversity of healthy options than their residential neighborhoods. Food shopping practices were also similar for food secure and food insecure women, although food insecure women more frequently shopped at discount stores. As there were no differences in exposure to discount stores by food security status, this finding suggests that food insecure women may navigate the same environment in different ways. Future research may wish to explore when and why women use food outlets outside of their residential neighborhoods and the role that discount stores play in low-income food landscapes, particularly for food insecure women.

There were few differences in objective food access by food security status. This finding is consistent with prior studies showing that objective measures of food access, specifically proximity to the nearest supermarket, are not associated with food security status.[14,15] Still, the existing evidence base is limited, and other studies have identified a positive association between distance to supermarkets and odds of food insecurity.[35] Importantly, our study is the first to examine multiple types of outlets along multiple dimensions of access, including density, proximity, and quality. Our unadjusted analyses indicated that food insecure women were located in closer proximity to unhealthy outlets, including convenience stores, discount stores, and limited service outlets, in their residential neighborhoods. However, our adjusted results suggest that these differences may be attributable to other factors related to food security status and the environments in which people live, such as income or car ownership. Still, it is worth noting that food access differed even within this socio-demographically similar population. There may be sub-populations within low-income communities who are at greater risk for the negative diet- and weight-related health outcomes associated with poor food access.

Our study is the first to compare the residential neighborhood and activity space food environments of food secure and food insecure women. While the quality of their residential food environments did not differ, food insecure women were exposed to healthier activity space environments. This finding suggests that food insecure women may seek out healthier environments in their routine travels. Prior to interpreting this finding, it may be useful to revisit what the mRFEI measures: the number of supermarkets in a given area relative to the total number of food outlets in the same area. Food insecure women may seek out environments with a greater number of supermarkets because such environments may provide additional opportunities to find food items aligned with their budgetary restrictions and other household needs. Further, although the association was not significant, it is worth noting that food secure women were exposed to healthier residential food environments than food insecure women. Thus, it remains possible that food insecure women traveled to healthier environments in an effort to overcome or compensate for their poorer residential food environments. The conditions under which food insecure women travel outside of their residential environments to access food, and the potential hidden costs of doing so (e.g. time and transportation), may benefit from additional study.

In contrast to several prior studies, perceptions of the food environment were not associated with food security status in adjusted analyses. Better perceived neighborhood food access was associated with lower odds of food insecurity in Philadelphia[13] and very low food insecurity among children in South Carolina.[14] However, our results may not be directly comparable with previous findings for several reasons. First, the Philadelphia study was conducted among a socioeconomically diverse sample; although the authors adjusted for income there may be additional unmeasured differences between high- and low-income populations for which they did not account. Second, the study in South Carolina, conducted among low-income families, categorized food security status into three levels, rather than two: food secure, food insecure, and very low food security among children. Similar to our study, the authors did not observe differences between food secure and food insecure families, but did observe differences between food secure families and families with very low food insecurity among children, the most severe form of food insecurity. These differences may be present in our sample as well, although they may be more difficult to detect given our smaller sample size. It is worth noting that our results are consistent with a study of low-income families in Toronto, which found no association between perceived adequacy of food retail access and food security status.[15] Additional research is needed to further clarify potential associations between perceptions of the food environment and food security status.

Consistent with prior research, food insecure women more frequently used discount stores.[36] Discount stores are dramatically changing the food landscape in urban and rural communities across the

U.S. Since 2011, two of the largest dollar store chains have grown from 20,000 locations to nearly 30,000 locations, with plans to open over 20,000 more stores.[37] In Atlanta, as in most urban areas, these stores are concentrated in low-income and predominantly African American communities.[38] The proliferation of discount stores has several important implications for diet- and weight-related health. First, discount stores generally offer a limited selection of primarily processed food items and infrequently stock fresh produce and other perishable items. At the same time, because they offer staple food and non-food items (e.g. paper towels, cleaning supplies) at low price points, they may make it more difficult for existing full-service grocery stores to compete and diminish any incentives new full-service grocery stores have to locate nearby.[37] Further, while individual items tend to have low prices, prices per unit may actually be higher than comparable items at big box retailers and club stores.[37,39] When, why, and how low-income families shop at discount stores has received limited attention in the food environment literature. In one recent exception, Caspi et al.[40] found that adults in Minnesota purchased a substantially higher number of calories at dollar stores than any other small food retailers including corner stores, gas stations, and pharmacies, and their primary reasons for shopping at dollar stores included proximity to home or work and good prices. For the food insecure women in our study, who had generally lower incomes and were less likely to have access to a car, low prices and proximity offer clear benefits, despite potentially detrimental effects on longer-term physical and financial health.

Despite differences in the use of discount stores, overall, food shopping practices differed minimally by food security status. We were somewhat surprised by these findings given prior research documenting the coping strategies food insecure families use to mitigate food insufficiency, such as relying on social support systems to borrow food or other resources, engaging in informal income generating activities, using charitable food sources, skipping payment for other routine costs (e.g. medications, utilities, rent), and purchasing bulk items, sale items, and expired or damaged foods.[41-43] As using a greater number of these coping strategies, and using them more frequently, have been associated with higher levels of food insecurity *within* low-income populations, we expected to observe similar differences in food shopping practices.[43,44] However, our results are consistent with a study of low-income

African American families in Baltimore, which found that the types of outlets where families purchased food were not associated with their food security status.[16] Although largely null, our results do still have implications for intervention development. Food environment researchers have become increasingly interested in understanding the food shopping practices of families living in areas with poor access to healthy foods.[45,46] As this area of research continues grow and inform the development of interventions seeking to improve diet- and weight-related health in underserved communities, it is important to understand differences within these communities that may modify intervention effectiveness. While our results suggest that food shopping practices do not vary substantially by food security status, additional research is still warranted, and previously identified coping strategies may benefit from additional attention.

To our knowledge, this is one of the first studies to examine differences by food security status in how frequently women shopped outside of their residential neighborhoods. Although results were not statistically significant, the descriptive differences we observed may help guide future research. It is not surprising that food insecure women were more likely to shop at supermarkets and limited service outlets within their residential neighborhoods, as far fewer food insecure women had access to a car. Car ownership may be an important, yet largely overlooked, factor influencing how low-income families navigate their food environments and the ultimate impact of these environments on their health.[47] Further, the saliency of car access is also likely to vary by the transportation culture and options available in a given city. Access to a car may be particularly important in cities like Atlanta characterized by urban sprawl and limited public transportation. That said, the majority of food secure and food insecure women in our study traveled outside of their residential neighborhoods to grocery shop, traveling more than twice the distance of their nearest supermarket, a pattern observed in a number of other studies.[48-51] Transportation costs may be an additional financial stressor for food insecure women already attempting to stretch limited resources for food and other necessities.

Our study was subject to several important limitations. While examining a comprehensive set of food access indicators (i.e. density, proximity, and quality) was a key strength of our study, there are other dimensions of access that we did not examine. Affordability may be particularly salient for food insecure families. Next, retail food outlet data are subject to a number of well-documented limitations, including the presence of outlets that are no longer in operation, the absence of outlets that have recently opened, and the misclassification of outlet types.[52] Still, we subjected our data to a rigorous data cleaning protocol and, in the absence of primary data collection, government sources are among the most accurate.[52] With regard to the measurement of activity space environments, because participants self-reported locations visited in the past month, data may be subject to recall, social desirability, and other related biases. By design, VERITAS only captures a subset of routine locations and does not assess the routes participants use to travel between locations. Thus, there may be other areas of exposure salient to food insecurity that we did not capture. Finally, our sample was not randomly selected and results may not be generalizable to other low-income African American families.

Conclusion. Interventions seeking to improve food environments and food shopping practices in low-income communities may not require special tailoring by food security status. Still, evidence for how the food environment may exacerbate or mitigate food insecurity remains limited, and requires further research. Our results suggest that discount stores may be a particularly relevant source of food for food insecure women. Future interventions will likely need to contend with their increasing prominence in low-income food landscapes. Our results also serve as an important reminder that the food environment is not confined to the residential neighborhood. Examining women's broader activity spaces provided additional insights into how women interacted with their environments. The possibility that food insecure women seek out food environments with a greater number of healthy options has important implications for intervention development. Increasing our knowledge of who, when, why, and where low-income families seek food outside of their residential environments can help ensure that efforts to make food environments and food shopping practices more supportive of healthy eating are aligned with women's actual experiences, perceptions, and preferences.

Table 4.1 Characteristics of low-income African American women in Atlanta, GA, by food security status (n = 199)

	Food secure (n=98)		**Food insecure (n=101)**		
	N or *Mean*	% or *SD*	*N* or *Mean*	% or *SD*	*p-value*
Age (*mean, SD*)	30.3	6.1	33.6	6.9	**<0.001**
Education (*n, %*)					0.12
Less than high school	9	9.2	18	17.8	
HS diploma or GED	45	45.9	40	39.6	
Some college/technical school	31	31.6	23	22.8	
Associate's degree or higher	13	13.3	20	19.8	
Employment status (*n, %*)					0.75
Full-time	39	39.8	35	34.6	
Part-time	20	20.4	19	18.8	
Unemployed, seeking employment	21	21.4	28	27.8	
Unemployed, not seeking employment	18	18.4	19	18.8	
Marital status *(n, %*)					**0.02**
Currently married	15	15.3	7	6.9	
Not married, living with partner	12	12.2	9	8.9	
Never married	69	70.4	74	73.3	
Divorced/separated/widowed	2	2.0	11	10.9	
Household size (*mean, SD*)	4.2	1.5	3.9	1.7	0.20
Income (annual) (*n, %*)					0.06
Less than $5,000	28	28.6	27	26.7	
$5,000-$9,999	16	16.3	15	14.9	
$10,000-$19,999	16	16.3	31	30.7	
$20,000-$29,999	15	15.3	17	16.8	
Greater than $30,000	23	23.5	11	10.9	
Car ownership (*n, %*)					**0.01**
Yes	71	72.4	55	54.5	
No	27	27.6	46	45.5	

SNAP benefits (*n*, *%*)					0.53
Yes	75	76.5	82	81.2	
No	23	23.5	19	18.8	
Area-level median household income	44155.8	15310.1	43985.9	14624.0	0.94

Table 4.2 Comparing food access in the residential neighborhood and activity space environments by food security status (n=199)

	Food secure (n=98)			**Food insecure (n=101)**					
	1-mile residential road network (ref)[a]	*Activity space points, weighted (hours/month)*	*Activity space points, unweighted*	*1-mile residential road network (ref)*[a,b]		*Activity space points, weighted (hours/month)*		*Activity space points, unweighted*	
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*p*	*M (SD)*	*p*	*M (SD)*	*p*
Supermarkets									
Density (retailers/mi^2)	0.17 (0.12)	0.19 (0.11)**	0.25 (0.08)***	0.17 (0.12)	0.96	0.19 (0.12)***	0.86	0.25 (0.08)***	0.97
Proximity (distance to closest retailer) (miles)	1.68 (1.02)	1.62 (0.82)	1.22 (0.29)***	1.63 (0.85)	0.67	1.58 (0.73)†	0.72	1.17 (0.29)***	0.28
Convenience stores									
Density (retailers/mi^2)	3.52 (2.43)	3.66 (2.11)	4.67 (1.57)***	3.71 (2.55)	0.6	3.89 (2.16)	0.44	4.55 (1.39)***	0.57
Proximity (distance to closest retailer) (miles)	0.59 (0.51)	0.53 (0.42)**	0.27 (0.10)***	0.45 (0.35)	**0.02**	0.43 (0.29)	**0.04**	0.25 (0.09)***	0.11
Discount stores									
Density (retailers/mi^2)	0.43 (0.17)	0.41 (0.14)*	0.42 (0.08)	0.45 (0.16)	0.34	0.44 (0.14)	0.19	0.44 (0.08)	0.15
Proximity (distance to closest retailer) (miles)	1.18 (0.95)	1.14 (0.73)	0.90 (0.27)**	0.98 (0.52)	**0.07**	1.01 (0.42)	0.13	0.89 (0.24)†	0.70
Limited service outlets									
Density (retailers/mi^2)	4.96 (6.25)	6.18 (5.28)**	11.28 (5.02)***	6.12 (8.83)	0.29	7.27 (7.82)**	0.25	10.51 (5.06)***	0.28
Proximity (distance to closest retailer) (miles)	0.75 (0.67)	0.65 (0.55)***	0.29 (0.12)***	0.59 (0.40)	**0.05**	0.55 (0.35)*	0.11	0.28 (0.10)***	0.48
mRFEI	2.39 (1.76)	2.40 (1.50)	2.29 (0.82)	2.16 (1.46)	0.69	2.17 (1.25)	0.76	2.37 (0.81)†	0.51
Perceived grocery environment	3.58 (1.21)	-	-	3.33 (1.30)	0.16	-	-	-	-
Perceived restaurant environment	2.42 (1.25)	-	-	2.07 (1.20)	**0.04**	-	-	-	-

[a] For proximity measures, this column displays distance from the residential address to nearest outlet
[b] n=99 for residential neighborhood environment because two participants did not share their residential address
† p<.10; * p<.05; ** p<.01; *** p<.0001

Notes. P-values indicated by symbols represent differences between environment types within each stratum of food security status (e.g. supermarket density in the 1-mile residential road network vs. supermarket density in the unweighted activity space *among* food secure women). P-values indicated by numeric values represent differences in food access between the food environments of food secure and food insecure women (e.g. supermarket density in the 1-mile residential road network for food secure women vs. supermarket density in the 1-mile residential road network for food insecure women). mRFEI = modified Retail Food Environment Index

Table 4.3 Associations between food security status and objective and perceived food access (n=199)

	1-mile residential road network [a,b]								*Activity space points, weighted (hours/month)*								*Activity space points, unweighted*							
	Unadjusted				*Adjusted*				*Unadjusted*				*Adjusted*				*Unadjusted*				*Adjusted*			
	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value
Supermarkets																								
Density (retailers/mi^2)	1.00	0.89	1.13	0.96	0.95	0.70	1.30	0.73	1.02	0.81	1.29	0.86	0.95	0.68	1.33	0.77	0.99	0.70	1.41	0.97	1.03	0.66	1.62	0.89
Proximity (distance to closest retailer) (miles)	0.98	0.91	1.06	0.67	0.96	0.85	1.07	0.42	0.98	0.89	1.08	0.72	0.96	0.84	1.10	0.51	0.88	0.69	1.11	0.28	0.80	0.60	1.07	0.13
Convenience stores																								
Density (retailers/mi^2)	1.00	0.98	1.02	0.59	1.00	0.98	1.02	0.96	1.01	0.99	1.03	0.44	1.00	0.99	1.02	0.85	0.99	0.98	1.01	0.57	**0.98**	**0.96**	**1.00**	**0.09**
Proximity (distance to closest retailer) (miles)	**0.82**	**0.69**	**0.98**	**0.03**	0.86	0.69	1.06	0.15	**0.81**	**0.65**	**1.00**	**0.05**	0.86	0.67	1.11	0.24	0.54	0.26	1.14	0.11	0.78	0.33	1.85	0.58
Discount stores																								
Density (retailers/mi^2)	1.09	0.91	1.30	0.34	1.02	0.84	1.24	0.85	1.14	0.94	1.39	0.19	1.08	0.85	1.37	0.50	1.31	0.90	1.90	0.15	1.34	0.87	2.06	0.19
Proximity (distance to closest retailer) (miles)	**0.91**	**0.82**	**1.00**	**0.08**	0.94	0.83	1.06	0.33	0.91	0.81	1.02	0.14	0.96	0.83	1.11	0.62	0.95	0.72	1.25	0.70	1.03	0.75	1.41	0.84
Limited service outlets																								
Density (retailers/mi^2)	1.00	1.00	1.01	0.29	1.00	1.00	1.01	0.35	1.00	1.00	1.01	0.26	1.00	1.00	1.01	0.44	1.00	0.99	1.00	0.28	**0.99**	**0.99**	**1.00**	**0.08**
Proximity (distance to closest retailer) (miles)	**0.87**	**0.76**	**1.01**	**0.06**	0.89	0.75	1.06	0.19	0.87	0.74	1.03	0.12	0.93	0.76	1.14	0.50	0.79	0.41	1.51	0.48	1.07	0.51	2.25	0.86
mRFEI	0.91	0.77	1.09	0.31	0.97	0.78	1.21	0.79	0.88	0.72	1.09	0.24	0.95	0.74	1.22	0.68	1.13	0.80	1.59	0.49	**1.46**	**0.94**	**2.26**	**0.09**
Perceived grocery environment	0.85	0.68	1.07	0.16	0.96	0.75	1.24	0.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perceived restaurant environment	**0.79**	**0.63**	**1.00**	**0.05**	0.88	0.68	1.13	0.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a] n=197 for residential neighborhood environments because two participants did not share their residential address
[b] For proximity measures, this column displays distance from the residential address to nearest outlet
* p<.05; ** p<.01; *** p<.0001
Notes. mRFEI = modified Retail Food Environment Index

Table 4.4 Food shopping practices of low income African American women in Atlanta, GA, by food security status (n=199)

	Food secure (n=98)		**Food insecure (n=101)**		
	N or *Median*	% or *IQR*	*N* or *Median*	% or *IQR*	*p-value*
Supermarkets					
Used outlet type (past month) (*n, %*)	95	96.9	99	98.0	0.68
Number of unique outlets used (past month) (*median, IQR*) [a]	2.0	2.0-3.0	2.0	1.0-3.0	0.28
Trip frequency (per month) (*median, IQR*) [a]	4.8	2.0-8.7	4.3	2.0-8.0	0.26
Proximity from home (miles) (*median, IQR*) [a]	3.7	2.4-5.9	3.4	2.2-5.1	0.22
Any outlets used in 1-mile road network buffer (*n, %*) [a]	17.0	17.9	23.0	23.2	0.38
Amount spent grocery shopping (past week) (*median, IQR*)	150.0	71.3-250.0	125.0	70.0-230.0	0.41
Convenience store					
Used outlet type (past month) (*n, %*)	23	23.5	26	25.7	0.74
Number of unique outlets used (past month) (*median, IQR*) [a]	1.0	1.0-1.5	1.0	1.0-1.0	**0.09**
Trip frequency (per month) (*median, IQR*) [a]	11.2	4.3-27.2	21.7	9.0-30.4	0.23
Proximity from home (miles) (*median, IQR*) [a]	0.8	0.4-3.9	0.8	0.3-3.1	0.76
Any outlets used in 1-mile road network buffer (*n, %*) [a]	14.0	60.9	16.0	61.5	1.00
Discount store					
Used outlet type (past month) (*n, %*)	26	26.5	39	38.6	**0.07**
Number of unique outlets used (past month) (*median, IQR*) [a]	1.0	1.0-1.0	1.0	1.0-1.0	0.25
Trip frequency (per month) (*median, IQR*) [a]	4.3	3.0-11.9	8.7	2.5-13.0	0.80
Proximity from home (miles) (*median, IQR*) [a]	1.2	0.7-4.8	1.4	0.6-2.8	0.78
Any outlets used in 1-mile road network buffer (*n, %*) [a]	12.0	46.2	19.0	48.7	1.00
Limited service outlet					
Used outlet type (past month) (*n, %*)	83	84.7	84	83.2	0.92
Number of unique outlets used (past month) (*median, IQR*) [a]	2.0	1.0-3.0	2.0	1.0-3.0	0.98
Trip frequency (per month) (*median, IQR*) [a]	3.7	2.0-8.7	3.6	1.5-7.6	0.66
Proximity from home (miles) (*median, IQR*) [a]	2.9	1.6-5.3	2.9	1.8-5.1	0.73

Any outlets used in 1-mile road network buffer (*n*, *%*) [a]	21.0	25.3	28.0	33.3	0.31
Amount spent eating out (past week) (*median*, *IQR*)	24.0	13.3-57.7	20.0	0.0-50.0	0.21

[a] Among women who used the outlet type

Table 4.5 Associations between food security status and food shopping practices (n=199)

	Unadjusted				Adjusted			
	OR	95% CI		p-value	OR	95% CI		p-value
Supermarkets								
Used outlet type (past month)	1.56	0.26	9.56	0.63	2.99	0.42	21.14	0.27
Number of unique outlets used (past month)	0.80	0.59	1.08	0.14	0.84	0.60	1.18	0.33
Trip frequency (per month)	0.98	0.95	1.01	0.15	0.99	0.95	1.02	0.41
Proximity from home (miles)	0.92	0.82	1.03	0.13	0.95	0.84	1.08	0.47
Any outlets used in 1-mile road network buffer	1.39	0.69	2.80	0.36	1.39	0.63	3.04	0.41
Amount spent grocery shopping (past week)	1.00	1.00	1.00	0.16	1.00	1.00	1.00	0.38
Convenience store								
Used outlet type (past month)	1.13	0.59	2.16	0.71	1.04	0.51	2.13	0.91
Number of unique outlets used (past month)	**0.31**	**0.08**	**1.17**	**0.08**	0.35	0.08	1.49	0.16
Trip frequency (per month)	1.01	0.98	1.03	0.63	1.00	0.97	1.03	0.97
Proximity from home (miles)	1.01	0.92	1.12	0.79	1.13	0.91	1.41	0.28
Any outlets used in 1-mile road network buffer	1.03	0.33	3.25	0.96	0.73	0.15	3.58	0.70
Discount store								
Used outlet type (past month)	**1.74**	**0.95**	**3.18**	**0.07**	1.46	0.74	2.85	0.27
Number of unique outlets used (past month)	2.30	0.56	9.47	0.25	2.63	0.31	22.09	0.37
Trip frequency (per month)	1.01	0.96	1.06	0.67	**1.11**	**1.00**	**1.23**	**0.06**
Proximity from home (miles)	0.96	0.87	1.06	0.43	1.07	0.90	1.26	0.45
Any outlets used in 1-mile road network buffer	1.11	0.41	3.00	0.84	0.41	0.08	2.01	0.27
Limited service outlet								
Used outlet type (past month)	0.89	0.42	1.91	0.77	1.07	0.44	2.56	0.89
Number of unique outlets used (past month)	0.99	0.78	1.26	0.94	1.17	0.89	1.55	0.27
Trip frequency (per month)	0.99	0.93	1.06	0.79	1.01	0.94	1.09	0.73
Proximity from home (miles)	0.97	0.90	1.03	0.31	1.00	0.93	1.08	1.00
Any outlets used in 1-mile road network buffer	1.48	0.75	2.89	0.26	1.49	0.70	3.21	0.30
Amount spent eating out (past week)	1.00	0.99	1.00	0.27	1.00	0.99	1.01	0.82

References

1. Coleman-Jensen A, Rabbitt M, Gregory C, Singh A. *Household Food Security in the United States in 2017.* United States Department of Agriculture;2018.
2. Gundersen C, Ziliak JP. Food Insecurity And Health Outcomes. *Health Aff (Millwood).* 2015;34(11):1830-1839.
3. Bruening M, Dinour LM, Chavez JBR. Food insecurity and emotional health in the USA: a systematic narrative review of longitudinal research. *Public Health Nutr.* 2017;20(17):3200-3208.
4. Laraia BA. Food insecurity and chronic disease. *Advances in nutrition (Bethesda, Md).* 2013;4(2):203-212.
5. Sun J, Knowles M, Patel F, Frank DA, Heeren TC, Chilton M. Childhood Adversity and Adult Reports of Food Insecurity Among Households With Children. *Am J Prev Med.* 2016;50(5):561-572.
6. Coleman-Jensen A, Nord M. Food insecurity among households with working-age adults with disabilities. *USDA-ERS Economic Research Report.* 2013(144).
7. Hernandez DC, Marshall A, Mineo C. Maternal Depression Mediates the Association Between Intimate Partner Violence and Food Insecurity. *Journal of Women's Health.* 2013;23(1):29-37.
8. Gundersen C, Ziliak JP. Childhood Food Insecurity in the U.S.: Trends, Causes, and Policy Options. *The Future of Children.* 2014:1-19.
9. Walker JL, Holben DH, Kropf ML, Holcomb JP, Anderson H. Household food insecurity is inversely associated with social capital and health in females from Special Supplemental Nutrition Program for Women, Infants, and Children Households in Appalachian Ohio. *Journal of the American Dietetic Association.* 2007;107(11):1998-1993.
10. Dean WR, Sharkey JR. Food insecurity, social capital and perceived personal disparity in a predominantly rural region of Texas: An individual-level analysis. *Social Science & Medicine.* 2011;72:1454-1462.

11. Carter MA, Dubois L, Tremblay MS. Place and food insecurity: a critical review and synthesis of the literature. *Public Health Nutrition.* 2014;17(01):94-112.

12. Bartfeld J, Men F. Food Insecurity among Households with Children: The Role of the State Economic and Policy Context. *Social Service Review.* 2017;91(4):691-732.

13. Mayer VL, Hillier A, Bachhuber MA, Long JA. Food Insecurity, Neighborhood Food Access, and Food Assistance in Philadelphia. *J Urban Health.* 2014;91(6):1087-1097.

14. Ma X, Liese AD, Bell BA, et al. Perceived and geographic food access and food security status among households with children. *Public Health Nutrition.* 2016;19(15):2781-2788.

15. Kirkpatrick SI, Tarasuk V. Assessing the relevance of neighbourhood characteristics to the household food security of low-income Toronto families. *Public Health Nutrition.* 2010;13(7):1139-1148.

16. Vedovato GM, Surkan PJ, Jones-Smith J, et al. Food insecurity, overweight and obesity among low-income African-American families in Baltimore City: associations with food-related perceptions. *Public Health Nutr.* 2016;19(8):1405-1416.

17. Sharkey JR, Dean WR, Johnson CM. Association of household and community characteristics with adult and child food insecurity among Mexican-origin households in colonias along the Texas-Mexico border. *Int J Equity Health.* 2011;10.

18. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med.* 2009;36(1):74-81.

19. Black C, Moon G, Baird J. Dietary inequalities: What is the evidence for the effect of the neighbourhood food environment? *Health & Place.* 2014;27:229-242.

20. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P. Are neighbourhood food resources distributed inequitably by income and race in the USA? Epidemiological findings across the urban spectrum. *BMJ Open.* 2012;2(2):e000698.

21. Tiwari A, Aggarwal A, Tang W, Drewnowski A. Cooking at Home: A Strategy to Comply With U.S. Dietary Guidelines at No Extra Cost. *American Journal of Preventive Medicine.* 2017;52(5):616-624.

22. Matthews SA, Yang T-C. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist.* 2013.

23. Lucan SC. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *J Acad Nutr Diet.* 2015;115(2):205-212.

24. Chen X, Kwan M-P. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. *American journal of public health.* 2015;105(9):1734-1737.

25. Crawford TW, Jilcott Pitts SB, McGuirt JT, Keyserling TC, Ammerman AS. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health & Place.* 2014;30:215-225.

26. Zenk SN, Schulz AJ, Matthews SA. Activity space environment and eating and physical activity behaviors: A pilot study. *Health and Place.* 2011;17:1150 - 1161.

27. Christian WJ. Using geospatial technologies to explore activity-based retail food environments. *Spatial and Spatio-temporal Epidemiology.* 2012;3(4):287-295.

28. Kestens Y, Lebel A, Chaix B, et al. Association between Activity Space Exposure to Food Establishments and Individual Risk of Overweight. *PLoS ONE.* 2012;7(8):e41418.

29. Kestens Y, Lebel A, Daniel M, Thériault M, Pampalon R. Using experienced activity spaces to measure foodscape exposure. *Health & Place.* 2010;16(6):1094-1103.

30. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine.* 2012;43(4):440-450.

31. U.S. Bureau of Labor Statistics. Average hours per day spent in selected activities by employment status and sex https://www.bls.gov/charts/american-time-use/activity-by-emp.htm. Published 2017. Accessed April 4, 2019.

32. CDC. Census Tract Level State Maps of the Modified Retail Food Environment Index (mRFEI). In.

33. Green SH, Glanz K. Development of the Perceived Nutrition Environment Measures Survey. *Am J Prev Med.* 2015;49(1):50-61.

34. United States Department of Agriculture. U.S. Household Food Security Survey Module. In: Economic Research Service, United States Department of Agriculture; 2012.

35. Bartfeld JS, Ryu J-H, Wang L. Local Characteristics Are Linked to Food Insecurity Among Households With Elementary School Children. *Journal of Hunger & Environmental Nutrition.* 2010;5(4):471-483.

36. Ma X, Liese AD, Hibbert J, Bell BA, Wilcox S, Sharpe PA. The Association between Food Security and Store-Specific and Overall Food Shopping Behaviors. *Journal of the Academy of Nutrition and Dietetics.* 2017;117(12):1931-1940.

37. Institute for Local Self-Reliance. Dollar Store Impacts. Institute for Local Self-Reliance. https://ilsr.org/wp-content/uploads/2018/12/Dollar_Store_Fact_Sheet.pdf. Published 2018. Accessed June 3, 2019.

38. Donahue M, Bonestroo H. New Maps Show Alarming Pattern of Dollar Stores' Spread in U.S. Cities. Institute for Local Self-Reliance. https://ilsr.org/new-maps-dollar-stores-spread/. Published 2019. Accessed June 3, 2019.

39. Eskenazi J. Dollar stores are thriving - but are they ripping off poor people? *The Guardian*2018.

40. Caspi CE, Lenk K, Pelletier JE, et al. Food and beverage purchases in corner stores, gas-marts, pharmacies and dollar stores. *Public Health Nutrition.* 2017;20(14):2587-2597.

41. Anater AS, McWilliams R, Latkin CA. Food acquisition practices used by food-insecure individuals when they are concerned about having sufficient food for themselves and their households. *Journal of Hunger & Environmental Nutrition.* 2011;6:27-44.
42. Kempson K, Keenan DP, Sadani PS, Adler A. Maintaining food sufficiency: Coping strategies identified by limited-resource individuals versus nutrition educators. *Journal of nutrition education and behavior.* 2003;35(4):179-188.
43. Wood DK, Shultz JA, Edlefsen M, Butkus SN. Food coping strategies used by food pantry clients at different levels of household food security status. *Journal of Hunger & Environmental Nutrition.* 2006;1(3):45-68.
44. Pinard C, Smith TM, Calloway EE, Fricke HE, Bertmann FM, Yaroch AL. Auxiliary measures to assess factors related to food insecurity: Preliminary testing and baseline characteristics of newly designed hunger-coping scales. *Preventive Medicine Reports.* 2016;4:289-295.
45. Liese AD, Ma XN, Hutto B, Sharpe PA, Bell BA, Wilcox S. Food Shopping and Acquisition Behaviors in Relation to BMI among Residents of Low-Income Communities in South Carolina. *International Journal of Environmental Research and Public Health.* 2017;14(9):1075.
46. Dubowitz T, Zenk SN, Ghosh-Dastidar B, et al. Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutr.* 2015;18(12):2220-2230.
47. Bodor JN, Hutchinson PL, Rose D. Car ownership and the association between fruit and vegetable availability and diet. *Preventive Medicine.* 2013;57(6):903-905.
48. Hillier A, Cannuscio CC, Karpyn A, McLaughlin J, Chilton M, Glanz K. How Far Do Low-Income Parents Travel to Shop for Food? Empirical Evidence from Two Urban Neighborhoods. *Urban Geography.* 2011;32(5):712-729.
49. LeDoux TF, Vojnovic I. Going outside the neighborhood: The shopping patterns and adaptations of disadvantaged consumers living in the lower eastside neighborhoods of Detroit, Michigan. *Health & Place.* 2013;19:1-14.

50. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and Supermarket Access: Proximity or Price? *American journal of public health.* 2012;102(8):e74-e80.

51. Ver Ploeg M, Mancino L, Todd JE, Clay DM, Scharadin B. *Where Do Americans Usually Shop for Food and How Do They Travel To Get There? Initial Findings From the National Household Food Acquisition and Purchase Survey.* United States Department of Agriculture, Economic Research Service;2015.

52. Fleischhacker SE, Evenson KR, Sharkey J, Pitts SBJ, Rodriguez DA. Validity of Secondary Retail Food Outlet Data: A Systematic Review. *American Journal of Preventive Medicine.* 2013;45(4):462-473.

Chapter 5: Conclusion

Summary of findings

In this dissertation, we used an activity space approach to refine how ‘exposure’ to the food environment is defined and measured and to examine how food access is associated with food shopping practices, dietary intake, and BMI among low-income African American women in Atlanta, GA. We found that food access differed substantially between the residential neighborhood and activity space environments. In particular, food outlet density was higher and distance to the nearest food outlet was shorter in the activity space compared to the residential neighborhood. Despite these differences, associations between food access and food shopping practices, dietary intake, and BMI did not differ by environment type. Food access in the residential neighborhood *and* the activity space was associated with food shopping practices and BMI, while food shopping practices were associated with dietary intake. Importantly, the nature of these associations varied considerably by outlet type. Finally, we found limited evidence that food environments or food shopping practices varied by food security status. We discuss each of these findings in additional detail below.

Residential neighborhood and activity space environments were different. Our findings support and extend the limited body of literature indicating that activity space environments differ from residential neighborhoods. Consistent with prior research, we found that food outlet density was higher in the activity space than the residential neighborhood.[1-3] Our study was the first to compare two additional dimensions of food access—geographic proximity and quality—across residential neighborhood and activity space environments. We found that women’s routine activity locations were located in closer proximity to food outlets than were their homes, and their activity spaces were slightly less healthy than their residential neighborhoods. Higher density and closer proximity in the activity space environments are likely attributable to urban zoning ordinances that place different usage restrictions on residential and commercial land. Results may differ for cities with different land use patterns, and may change as more cities introduce zoning reforms that promote mixed-use development.[4]

Given differences between the residential neighborhood and activity space food environments, we expected associations between food access and food shopping practices, dietary intake, and BMI to vary by environment type. Specifically, we expected activity space measurement approaches to result in more theoretically consistent associations with diet- and weight-related health, as they provide a more comprehensive measure of the environments to which people are exposed. However, as we discuss next, this remains an open question.

Associations between food access and food shopping practices, dietary intake, and BMI did not differ by environment type. Contrary to our expectations, activity space measures did not result in more theoretically consistent associations between food access and diet- and weight-related health behaviors and outcomes, and, in fact, some observed associations were only present in the residential environment. Very few studies have compared associations between food access and health across residential neighborhood and activity space environments. Our results are consistent with findings from some studies,[5] but inconsistent with findings from others.[6,7] As such, our results should be viewed as contributing to the development of a currently limited evidence base, rather than providing decisive evidence regarding the relative importance of residential neighborhood versus activity space measurement approaches.

There are several potential explanations for our findings. First, it is possible that differences between the residential neighborhood and activity space environments were not meaningful in practice. In other words, the locations women routinely visited may be located in environments that are generally similar to their residential neighborhoods. In the U.S., people are sorted by race and class into environments that are not only separate, but qualitatively different.[8,9] This segregation may extend to the broader environments through which women travel,[10] ultimately confining them to particular types of residential and non-residential environments. Another potential explanation for our findings is that residential environments are particularly salient areas of exposure. Residential environments serve as a key anchor point around which many activities of daily life revolve. Thus, the food-related norms and behaviors that dominate in the residential environment may be particularly influential in patterning food shopping practices and other diet- and weight-related behaviors, even among women who shop outside of their residential neighborhoods.[11] Finally, our results may be attributable to methodological limitations, such as residual confounding due to residential self-selection, or our approach to measuring activity spaces, which we discuss in detail below.

Food access was associated with food shopping practices and BMI, but the most salient dimensions of access varied by outlet type. Food access was associated with food shopping practices and BMI, but the most salient dimensions of access varied by outlet type. Specifically, exposure to a higher *density* of supermarkets was associated with using supermarkets closer to home, while closer *proximity* to limited service outlets was associated with using limited service outlets closer to home. Further, being located farther away from ‘unhealthy’ outlets, including convenience stores, discount stores, and limited service outlets, was associated with lower BMI.

Our results highlight the importance of recognizing that food access is a multidimensional construct, and that the salience of each dimension likely depends on a person’s primary motivations for using a particular type of outlet. The choice to use a particular supermarket is likely driven by numerous factors including cleanliness, availability of culturally relevant food items, family friendliness, accessibility from public transportation, affordability, and more.[12-14] Being exposed to a higher density of supermarkets may provide women with more opportunities to fulfill these diverse criteria. While proximity alone is not enough to determine use, once these criteria are met, she may be more likely to use a supermarket closer to home.

The use of unhealthy food outlets is likely driven by a different set of criteria. Convenience is one of the key reasons cited for using limited service outlets, convenience stores, and discount stores. As such, the outlets women choose to utilize are likely selected from among nearby options, and women located farther away from these outlets may be less inclined to go out of their way to find one. Further, the decision to use limited service outlets, convenience stores, and discount stores, may be prompted by exposure to the outlet in the first place.[15,16] Obesogenic environments stimulate the desire to eat through various neurophysiological pathways, which humans have limited capacity to control.[17] Women located farther away from unhealthy outlets may encounter these environmental cues less frequently, resulting in less consumption and a lower BMI.

As such, we were surprised that we did not observe similar associations between farther distance to unhealthy outlets and more healthful dietary patterns. This may be explained by the fact that BMI is a more distal outcome than dietary intake, and food access may be correlated with other features of the environment, such as walkability or green space, that also affect BMI.[18] Food access may be one component in a complex network of environmental influences on BMI, making it more difficult to identify precise intermediary pathways.

Food shopping practices were associated with dietary intake. While *access* to unhealthy outlets was not associated with dietary intake, the *use* of limited service outlets—specifically, using a larger number of limited service outlets, using limited service outlets more frequently, and spending more money eating out—was associated with a less healthful dietary pattern. Our results highlight the importance of examining both food access *and* food shopping practices. This may be particularly important for limited service outlets, given their ubiquity in urban communities across the U.S. While differences in access remain, as evidenced by the association between proximity and BMI discussed above, individual-level factors may also help explain why some women purchase fast food more frequently than others. Convenience, cost, and taste are some of the key reasons people consume fast food, despite knowledge of its health effects.[15,19] These incentives may be more or less salient depending on a woman's individual resources and constraints, such as her employment status, financial obligations, access to transportation, and more.

In contrast to limited service outlets, supermarket shopping practices were not associated with dietary intake, demonstrating, again, the relevance of outlet type. This may be attributable to the particular shopping practices we chose to examine. While knowing how frequently a woman purchases food at a limited service outlet provides a relatively clear indication that she is consuming some amount of unhealthy food, knowing how frequently a woman goes to the supermarket does not offer much insight into the types of foods she is purchasing or consuming.

Food environments and food shopping practices varied minimally by food security status. Finally, we turned our attention to potential differences within our socio-demographically similar sample, and examined how the experience of food insecurity may affect the way in which women experience or interact with their food environments. Overall, we found limited evidence that food secure and food insecure women were exposed to different food environments or engaged in different food shopping practices. Still, our study was the first to compare the residential neighborhood and activity space food environments of food secure and food insecure women, and we found some evidence to suggest that food insecure women were exposed to healthier activity space environments. Food insecure women may travel to environments with a greater number of supermarkets in order to increase the likelihood that they are able to find food items aligned with their budgetary restrictions and other household needs. Further, while there were no significant differences in the quality of women's residential environments, descriptively, food secure women were exposed to healthier residential environments. It is possible that food insecure women seek out healthier environments to compensate for poorer access in their residential neighborhoods.

Strengths

Our study has a number of notable strengths. First, and foremost, our study is one of very few that have used an activity space approach to examine associations between the food environment and diet- and weight-related health. Activity space approaches represent a potentially important advancement in place-based health research as they provide a more comprehensive assessment of the environments to which people are exposed. As the number of food environment researchers advocating for the use of activity space approaches increases, building the currently limited evidence base is of critical importance. Our study also compared multiple definitions of the residential neighborhood and activity space environments. As we will discuss below, these comparisons offer important insights into how future research findings may vary by the approach used to define and measure the environment. Our study also sought to account for the widely acknowledged, but infrequently addressed, issue of selective daily mobility bias. Prior studies that have identified associations between activity space food environments and dietary intake/BMI were unable to address potential biases due to their use of GPS-defined activity spaces, which provide spatial and temporal data on the locations visited, but typically do not provide detail on location type.

Our methods for defining and measuring food access also have a number of strengths. As discussed in detail above, our findings highlighted the multidimensionality of food access and demonstrated how the most salient dimensions of access may vary by outlet type. We were able to draw these important conclusions because we examined multiple dimensions of access across multiple types of food outlets. A large portion of existing food environment research has examined only one or two dimensions of access at a time, and has largely focused on supermarkets and fast food outlets. Further, our use of kernel density estimation to calculate outlet density and quality has advantages over more commonly used approaches, which either count the number of outlets in a given area or calculate the density of outlets per area or per person. Unlike kernel density estimation, the first approach does not account for the likelihood that the environments to which people are exposed vary in size, while the latter approach does not account for the possibility that outlets located in closer proximity may be more influential than outlets located farther away.

Another important strength of our study was the examination of both food access and actual food shopping practices. A large portion of existing food environment research does not include data on where people actually purchase food. These studies implicitly assume that the food outlets to which people are exposed accurately represent the food outlets they use. However, food environments, particularly in urban U.S. settings, typically contain a multiplicity of food outlets, both healthy and unhealthy, and people do not use every outlet to which they are exposed. By examining actual food shopping practices, we explicitly acknowledge that people may navigate the same environment in different ways, and that place effects on health are best understood as resulting from dynamic rather than static relationships between people and places.

Finally, although poor access to affordable, healthy foods and high levels of food insecurity often coexist within low-income communities and communities of color, very little research has considered whether features of the food environment may affect a household’s ability to access adequate food. Our study is one of very few to examine how food access and food shopping practices may vary by household food security status. Although we ultimately identified limited differences, our results underscore the importance of examining sources of variation within underserved communities that may modify the effectiveness of place-based interventions.

Limitations

Despite these strengths, our study is subject to a number of limitations. The VERITAS questionnaire collects self-reported data on participant's routine activity locations.[20] As a result, data may be subject to recall, social desirability, and other attendant biases. However, the questionnaire is designed to aid recall by prompting participants about 21 different types of locations. Further, one interviewer administered all questionnaires in order to minimize interviewer effects. The interviewer also kept detailed notes on the administration of each questionnaire, which enabled the exclusion of four participants for whom there were concerns regarding data quality or completeness. Another limitation of the VERITAS questionnaire is that it does not collect data on the routes participants use to travel between locations. Depending upon the mode of transportation, these routes may represent important areas of exposure. Further, the questionnaire only asks about a subset of locations and there may be additional environments to which participants are routinely exposed.

The secondary retail food outlet data we used to measure food access is also subject to several limitations, which may have further affected our ability to accurately characterize the environments to which women were exposed. Validation studies indicate that secondary food outlet datasets, to varying degrees, may include retailers that are no longer open and exclude retailers that have opened since the dataset was last updated.[21] However, we have no reason to believe that these inaccuracies are non-randomly distributed across participant activity spaces. Further, in the absence of primary data collection, government registries are among the most accurate.[21] The misclassification of food outlet types is another possible limitation. We primarily relied on the categories pre-established by the GDPH and GDA, but without on-the-ground verification, we cannot determine their accuracy. It should also be noted that our study focused exclusively on the *community food environment*, or the number, type, and location of food retailers within a community. Although beyond the scope of this study, other types of food environments, such as the home food environment (e.g. availability, placement, and preparation of food item within the home), the school and worksite food environments (e.g. cafeteria and vending machine offerings), and the consumer food environment (e.g. price, promotion, and placement of food items within outlets), all have important implications for diet- and weight-related health.[22]

Finally, our study sample was not randomly selected and is not intended to be generalizable to the broader population of low-income African American women in Atlanta, GA or elsewhere. Further, all data are cross-sectional and we cannot draw any conclusions regarding the temporality of observed associations. In addition, residential self-selection, or the presence of unmeasured attributes related to neighborhood choice and the health outcomes of interest, is a critical source of bias in studies estimating associations between neighborhoods and health. We cannot rule out the possibility of residual confounding, particularly in analyses where the residential food environment was the independent variable. However, because residential segregation by race and class is one of dominant forces sorting people into neighborhoods in the U.S., we believe that selection bias may be less of an issue in our racially and socioeconomically homogeneous sample.

Implications for research

Activity space research. At their core, activity space approaches seek to add nuance and precision to our understanding of how environmental exposures across time and space affect our health.[23] In our study, activity space measures provided a more comprehensive picture of the environments to which women were routinely exposed, and captured a much higher proportion of the food outlets women actually used. However, despite these differences, the use of an activity space approach did not result in more theoretically consistent associations with diet- or weight-related health. Additional research is needed to help clarify how the strengths, limitations, and assumptions underlying different approaches to the measurement of activity spaces may impact findings.

Thinking more precisely about the environments to which people are exposed, requires consideration of how exposures may change over time. Our study provided a snapshot of women's current monthly routines, largely ignoring their 'exposomes', or the accumulated environments to which they are exposed over the life course. Cross-sectional data limits our ability to examine how the food environments to which women have been exposed over time—and the food shopping practices that have developed in tandem with these exposures—have helped shape their current diet- and weight-related behaviors and outcomes. Prior research indicating that dietary behaviors are developed early in life,[24] suggests that the food environments to which women are exposed in childhood and adolescence may be particularly relevant to their current health. Although tracking environmental exposures over time presents obvious data collection challenges, researchers may benefit from the use of complementary qualitative methods. Geo-ethnographic methods, which integrate geospatial and ethnographic data, may help elucidate how exposures and behaviors change across space and time.[25] Residential histories and the collection of activity space data from diverse age groups, such as adolescents and older adults, may also help advance our understanding of the temporal dimensions of place-based exposures.

Activity space approaches also raise the question of whether there are particular locations that have a stronger influence on health behaviors or outcomes than others. Weighting women's activity spaces by the frequency and duration of her visit to each location assumed that the more time a woman spends in a particular location, the greater influence it may have on her health. Future research can explicitly examine this question by comparing various non-nested environments. Separate residential and non-residential environments can be created to assess whether, and how, they are independently associated with health behaviors and outcomes. Researchers can also construct additional environments for other locations they believe to be particularly influential, such as schools or workplaces. In using these approaches, activity space researchers will need to continue addressing potential biases due to residential self-selection and selective daily mobility. For those using GPS tracking to measure activity spaces, this may require the integration of supplementary surveys or ecological momentary assessments to collect data on the type of locations visited.

Additional research is also needed to compare different approaches to defining and measuring activity spaces. Our results raised questions regarding the utility of the convex hull polygon, which includes a significant amount of space to which people are not actually exposed. Unlike the other residential neighborhood and activity space environments we examined, food access in the convex hull polygon, for the most part, was not associated with food shopping practices. Future researchers should carefully consider their research aims when deciding to use convex hull polygons, or other summary measures like standard deviational ellipses, to define the activity space. Such measures may be more useful in representing the overall size, dispersion, and directionality of activity spaces, than in defining exposures. More research comparing the use of self-reported questionnaires and GPS tracking is also needed. Although a recent validation study compared the locations captured by VERITAS versus GPS tracking,[26] researchers have not yet assessed impacts on the estimation of health effects. Finally, additional research is needed to compare the use of different recall or tracking periods (e.g. daily, weekly, monthly), as well as different approaches to time weighting (e.g. frequency, duration, both).

Food environment research. Overall, our findings suggest that future research would benefit from increased attention to the multidimensionality of food access, the different outlet types that comprise food landscapes, and the diverse factors that influence a woman's decision to use some outlets over others.

Whenever possible, researchers should investigate multiple dimensions of access. Our results demonstrated that density may be particularly salient to understanding supermarket access and use, while proximity may be more relevant to 'unhealthy outlets', such as convenience stores, discount stores, and limited service outlets. While specific findings may differ across study settings and populations, researchers should consider how different dimensions of access theoretically relate to the types of outlets they have chosen to examine. Additional research is also needed to compare relative and absolute measures of access. Results from chapter two demonstrated that the associations between supermarket and convenience store density and BMI were attenuated after adjusting for the density of other outlet types. Future research should consider the possibility that observed associations are confounded by the co-location of different types of outlets. Using relative measures of access, such as the mRFEI, offers one potential solution to this issue. Finally, researchers should consider the influence of additional dimensions of access that are less amenable to quantitative assessment, such as accommodation and acceptability. Mixed methods and qualitative research approaches may be useful in advancing our understanding of the multidimensionality of access.

Researchers should also seek to examine multiple types of food outlets, beyond commonly studied supermarkets and fast food restaurants. Although supermarkets and limited service outlets were the only outlets used by the majority of women in our sample, convenience stores and discount stores may be an important source of calories for women who do use them. Women who shopped at convenience stores and discount stores, made a median of 17 and five trips per month, respectively. Shopping at discount stores was particularly common among food insecure women, who made nine trips per month. Discount stores are rapidly changing the food landscape in urban and rural communities across the U.S.[27] As stores continue to open at a rapid pace, future research should examine the ways in which they may alter food shopping practices, such as by displacing the use of smaller community grocery stores, and subsequent impacts on diet- and weight-related health. As discussed above, additional research is needed to determine how relative measures of access can help us understand food outlets as parts of an integrated and cohesive ‘foodscape’, rather than as isolated actors.

Food environment researchers must acknowledge the increasingly large body of evidence indicating that the majority of food shopping is conducted outside of conventionally defined residential neighborhood environments. Nearly 80% of the women in our sample traveled outside of their residential neighborhoods to shop, using supermarkets located more than twice as far away as the nearest option. While activity space approaches can offer insight into when and where women seek food beyond their residential neighborhoods, complementary qualitative research may be needed to understand why women frequently bypass closer options. Further, results from chapter four demonstrate that the answer to this question may vary by food security status or other individual- or household-level characteristics. While residential food environments did not differ by food security status, food insecure women were exposed to healthier activity space environments. Future research should examine whether some populations are more likely than others to shop outside of their residential neighborhoods, and assess the potential costs of doing so (e.g. transportation, time).

Implications for practice

Despite inconclusive evidence for the pathways through which food environments affect health, efforts to improve access to healthy, affordable foods in underserved communities have proliferated. However, many of these efforts—from federal funding programs incentivizing the development of new supermarkets[28] to local zoning regulations restricting the opening of fast food outlets[29]—have met with limited success. Developing effective interventions will likely require greater attention to the complex ways in which people navigate and interact with their food environments. Closer connections between research and practice can ensure that these interventions are both evidence-based and translatable.

The majority of efforts to improve access to healthy foods have involved opening new retailers, such as supermarkets, grocery stores, and farmers' markets, or modifying product mix and placement in existing retailers, such as corner and convenience stores. Initiatives to open new retailers are typically motivated by the assumption that residents of underserved areas are not consuming enough healthy foods, like fruits and vegetables, because the outlets at which they can obtain these foods are located too far away. However, nearly every woman in our sample already shopped at a supermarket, often traveling more than twice as far as the closest option, suggesting that proximity may not be the most important determinant of use. A newly *available* retailer is not necessarily an *accessible* retailer. To ensure that community members actually utilize newly opened outlets, future interventions must address the diverse dimensions of access that influence outlet choice. With regard to interventions designed to modify existing retailers, our results point to the importance of understanding the role that smaller retailers, like corner and convenience stores, play in various food landscapes. Only 25% of the women in our sample shopped at convenience stores, suggesting that the reach of such interventions may vary across settings. 'Healthy corner store initiatives' can still be useful as part of a broader strategy for improving food environments, but it is important to consider their potential for population-level impact if used on their own.

Less commonly, interventions have sought to improve food environments by reducing access to unhealthy foods. Our study demonstrated that, unlike supermarkets, proximity was the most salient dimension of access for 'unhealthy' outlets. Assuming that people are less likely to purchase food from limited service outlets if one is not immediately available, these findings lend support to interventions like the South Los Angeles 'fast food ban'.[29] However, in practice, such interventions face myriad challenges. As demonstrated by the case of South Los Angeles, such restrictions are unlikely to apply to all limited service outlets and typically only cover new construction, leaving an abundance of outlets still in place. Further, as our study demonstrated, people are exposed to, and utilize, many retailers outside of their residential neighborhoods. Given the ubiquity of fast food outlets in particular, people will likely continue to have substantial access to fast food even if restrictions limit their opening in certain areas. Other intervention strategies that rely on governments to regulate access to unhealthy foods, such as sugar-sweetened beverage taxes,[30] container size restrictions,[31] and trans fats bans,[32] may have more far-reaching effects. However, such strategies also require engagement with more complicated questions about paternalism and free choice.

Our study also speaks to the importance of considering the entire 'foodscape' when designing community-level interventions. Women were exposed to, and used, a wide variety of food outlets, and their food shopping practices varied significantly by outlet type. Exclusively focusing on improving access to healthy foods *or* reducing access to unhealthy foods ignores the likelihood that women use different types of food outlets for different reasons. Opening a new supermarket, even one that successfully increases the consumption of healthy foods, will not change the fact the fast food outlets remain a convenient and inexpensive source of prepared foods. Multicomponent interventions that improve the overall quality of the food environment will likely be needed to effect population-level changes in diet- and weight-related health. Interventions will also need to consider the timeframe within which changes are likely to occur. Many residents of underserved communities have been exposed to poor quality food environments for their entire lives, and their dietary behaviors have developed within the confines of their surroundings. It is likely unreasonable to expect that improvements to the food environment—while a necessary precondition—will immediately change longstanding food shopping, purchasing, and consumption behaviors.

Our results also highlight the need for multilevel interventions that improve the food environments in which people make diet-related decisions *and* ensure that they have the individual-level resources needed to make healthy choices. In our study, women with greater access to limited service outlets did not use them more frequently, but women who used them more frequently had less healthful dietary patterns. To ensure that all community members benefit from interventions implemented at higher levels of the social ecology, it is necessary to understand why decision-making processes vary even within socio-demographically similar communities. Multilevel interventions may require consideration of, and tailoring to, a variety of individual-level resources and constraints, such as finances, time budgets, social support, mental health, knowledge, skills, and habits. Developing and implementing interventions in collaboration with community members can serve as a powerful tool for understanding and responsibly addressing these internal nuances.

Conclusion

Understanding the pathways through which food environments affect health is critical to the development of evidence-based interventions that improve food environments and make them more supportive of healthy eating. This study aimed to advance current understanding by addressing several key methodological challenges facing food environment research, including a reliance on neighborhood-based measures of exposure, a lack of data on how people *interact* with their food environments, including where, when, and how they acquire food, and limited attention to differences *within* underserved communities that may affect food outlet exposure and use. Findings underscore the need to move away from conceptualizing the food environment as a singular and static entity that uniformly affects diet- and weight-related health, toward a dynamic understanding of how individual and environmental characteristics interact to influence health behaviors and outcomes. While activity space approaches more precisely represent the environments to which people are exposed, they do not offer a magic bullet for understanding the complex pathways through which food environments affect health. Continued examination of exposure *and* use, acknowledgement of the multidimensionality of access, and attention to the unique food environments women create as they move through their daily lives, will provide much needed insight into how food environments can be modified to be more supportive of healthy eating.

References

1. Kestens Y, Lebel A, Daniel M, Thériault M, Pampalon R. Using experienced activity spaces to measure foodscape exposure. *Health & Place.* 2010;16(6):1094-1103.
2. Crawford TW, Jilcott Pitts SB, McGuirt JT, Keyserling TC, Ammerman AS. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health & Place.* 2014;30:215-225.
3. Christian WJ. Using geospatial technologies to explore activity-based retail food environments. *Spatial and Spatio-temporal Epidemiology.* 2012;3(4):287-295.
4. City of Atlanta. Zoning Ordinance Update for the City of Atlanta. https://www.zoningatl.com/. Published 2019. Accessed April 6, 2019.
5. Tamura K, Elbel B, Athens JK, et al. Assessments of residential and global positioning system activity space for food environments, body mass index and blood pressure among low-income housing residents in New York City. *Geospatial health.* 2018;13(2).
6. Zenk SN, Schulz AJ, Matthews SA. Activity space environment and eating and physical activity behaviors: A pilot study. *Health and Place.* 2011;17:1150 - 1161.
7. Shearer C, Rainham D, Blanchard C, Dummer T, Lyons R, Kirk S. Measuring food availability and accessibility among adolescents: Moving beyond the neighbourhood boundary. *Social Science & Medicine.* 2015;133:322-330.
8. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Reports.* 2001;116(5):404-416.
9. Massey DS, Denton NA. The dimensions of residential segregation. *Social Forces.* 1988;67:281 - 315.
10. Jones M, Pebley A. Redefining Neighborhoods Using Common Destinations: Social Characteristics of Activity Spaces and Home Census Tracts Compared. *Demography.* 2014;51(3):727-752.

11. Clary C, Matthews SA, Kestens Y. Between exposure, access and use: Reconsidering foodscape influences on dietary behaviours. *Health & Place.* 2017;44:1-7.

12. Cannuscio CC, Hillier A, Karpyn A, Glanz K. The social dynamics of healthy food shopping and store choice in an urban environment. *Social Science & Medicine.* 2014;122:13-20.

13. DiSantis KI, Hillier A, Holaday R, Kumanyika S. Why do you shop there? A mixed methods study mapping household food shopping patterns onto weekly routines of black women. *The international journal of behavioral nutrition and physical activity.* 2016;13(1):11.

14. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and Supermarket Access: Proximity or Price? *American journal of public health.* 2012;102(8):e74-e80.

15. Dave JM, An LC, Jeffery RW, Ahluwalia JS. Relationship of attitudes toward fast food and frequency of fast-food intake in adults. *Obesity.* 2009;17(6):1164-1170.

16. Caspi CE, Lenk K, Pelletier JE, et al. Food and beverage purchases in corner stores, gas-marts, pharmacies and dollar stores. *Public Health Nutrition.* 2017;20(14):2587-2597.

17. Cohen DA. Neurophysiological Pathways to Obesity: Below Awareness and Beyond Individual Control. *Diabetes.* 2008;57(7):1768-1773.

18. Cummins S, Clary C, Shareck M. Enduring challenges in estimating the effect of the food environment on obesity. *The American journal of clinical nutrition.* 2017;106(2):445-446.

19. Garza KB, Ding M, Owensby JK, Zizza CA. Impulsivity and Fast-Food Consumption: A Cross-Sectional Study among Working Adults. *Journal of the Academy of Nutrition and Dietetics.* 2016;116(1):61-68.

20. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An Interactive Mapping Tool to Assess Individual Mobility Patterns in Neighborhood Studies. *American Journal of Preventive Medicine.* 2012;43(4):440-450.

21. Fleischhacker SE, Evenson KR, Sharkey J, Pitts SBJ, Rodriguez DA. Validity of Secondary Retail Food Outlet Data: A Systematic Review. *American Journal of Preventive Medicine.* 2013;45(4):462-473.

22. Glanz K, Sallis JF, Saelens BE, Frank LD. Healthy Nutrition Environments: Concepts and Measures. *American Journal of Health Promotion.* 2005;19(5):330-333.

23. Matthews SA, Yang T-C. Spatial Polygamy and Contextual Exposures (SPACEs): Promoting Activity Space Approaches in Research on Place And Health. *American Behavioral Scientist.* 2013.

24. Savage JS, Fisher JO, Birch LL. Parental Influence on Eating Behavior: Conception to Adolescence. *The Journal of Law, Medicine & Ethics.* 2007;35(1):22-34.

25. Matthews SA, Detwiler J, Burton LM. Geoethnography: Coupling geographic information analysis techniques with ethnography methods in urban research. *Cartographica.* 2005;40:75 - 90.

26. Zenk SN, Kraft AN, Jones KK, Matthews SA. Convergent validity of an activity-space survey for use in health research. *Health & Place.* 2019;56:19-23.

27. Donahue M, Bonestroo H. New Maps Show Alarming Pattern of Dollar Stores' Spread in U.S. Cities. Institute for Local Self-Reliance. https://ilsr.org/new-maps-dollar-stores-spread/. Published 2019. Accessed June 3, 2019.

28. Reinvestment Fund. About the Healthy Food Financing Initiative. https://www.investinginfood.com/about-hffi/. Accessed March 25, 2019.

29. Sturm R, Hattori A. Diet and obesity in Los Angeles County 2007–2012: Is there a measurable effect of the 2008 "Fast-Food Ban"? *Social Science & Medicine.* 2015;133:205-211.

30. Brownell KD, Farley T, Willett WC, et al. The Public Health and Economic Benefits of Taxing Sugar-Sweetened Beverages. *New England Journal of Medicine.* 2009;361(16):1599-1605.

31. Pomeranz JL, Brownell KD. Portion Sizes and Beyond — Government's Legal Authority to Regulate Food-Industry Practices. *New England Journal of Medicine.* 2012;367(15):1383-1385.

32. Brownell KD, Pomeranz JL. The Trans-Fat Ban — Food Regulation and Long-Term Health. *New England Journal of Medicine.* 2014;370(19):1773-1775.

Appendix. Retail food environment data cleaning protocol

A. Georgia Department of Agriculture (GDA) data (*supermarkets, grocery stores, convenience stores,* and *discount general merchandise stores*)

<u>Step 1: Geocoding</u>

We geocoded all address data using Google Maps' Geocoding API. There was a 100% match rate for the GDA dataset. We identified 12 geocoding errors (0.3%) when plotting the points. The errors resulted from minor inaccuracies in how addresses were listed in the dataset (e.g. NW after a street name rather than SW). We were able to correct these inaccuracies and successfully geocode each address.

<u>Step 2: Remove ineligible retailers</u>

The full dataset included 5,898 retailers. We began by deleting the following GDA categories deemed ineligible for inclusion:

1. Cottage Food Operation = 502
2. Prepackaged Food Only (e.g. Bed Bath & Beyond, Macy's, Burlington Coat Factory, Homegoods) = 333
3. Sushi bars located inside supermarkets = 173
4. Rolling Vending Stores = 42
5. Shared Time / Community Kitchen = 20
6. Water and Ice Vending = 16
7. Food Banks = 15
8. Retail Beverage Dispensary = 6
9. Salvage Food Dealer = 3
10. Food Storage Warehouse = 2
11. District Office = 1

12. Small Poultry Processing = 1

With a new total of 4,784, we hand searched the data for additional ineligible retailers. We deleted 98 additional retailers for the following reasons:

1. Airport = 57
2. Arena = 1
3. College/university = 5
4. Event venue = 1
5. Gift baskets = 24
6. Golf club = 2
7. Grocery delivery service = 1
8. Gym/fitness center = 2
9. Hotel = 2
10. Mobile unit = 2
11. Residential location = 1

Step 3: Remove duplicate retailers

With a new total of 4,686 we searched the data for duplicates. First, we identified retailers located at the same latitude and longitude with the same name. Once these were removed, we manually searched retailers located at the same latitude and longitude without an exact name match. Locations with very similar names (e.g. Kroger and The Kroger Co.) were considered duplicates. We deleted 108 duplicates for a new total of 4,578 retailers.

Step 4: Categorize retailers

We categorized each retailer into one of four categories: *supermarkets*, *grocery stores*, *convenience stores/pharmacies*, and *discount general merchandise stores*. We began by inspecting the existing categories that the GDA uses to classify retailers. We grouped the following GDA categories under our four broader categories:

Supermarkets

[200] Chain Store w/Sushi

[201] Chain Store w/Meat Market

[202] Chain Store w/Seafood, Deli, Bakery, Meat Market

[203] Chain Store w/Seafood, Deli, Meat Market

[204] Chain Store w/Seafood, Meat Market

[206] Chain Store w/Bakery, Meat Market

[207] Chain Store w/Deli, Bakery, Meat Market

Grocery Stores

[101] Retail Store w/Meat Market

[102] Retail Store w/Seafood, Deli, Bakery, Meat Market

[103] Retail Store w/Seafood, Deli, Meat Market

[104] Retail Store w/Seafood, Meat Market

[105] Retail Store w/Deli, Meat Market

[106] Retail Store w/Bakery, Meat Market

[107] Retail Store w/Deli, Bakery, Meat Market

[108] Retail Seafood

[109] Retail Seafood with Deli

[604] Health Food Store

[605] Health Food Store w/Deli

Convenience stores/pharmacies

[304] Retail / Convenience Store

[305] Retail / Convenience Store w/Deli

[306] Retail / Convenience Store w/Bakery

[307] Retail / Convenience Store w/Deli, Bakery

[503] Drug Store

Discount general merchandise stores

[504] Food Sales Area (with Potentially Hazardous Foods)

[505] Food Sales Area w/Deli

[506] Food Sales Area w/Bakery

We moved the following GDA categories to the *limited service* category in the GDPH dataset:

[208] Retail/Wholesale Bakery

[214] Retail Bakery

[215] Retail Bakery - Large

[217] Retail Bakery with Deli

[242] Retail Candy Processing

[384] Retail Juice Processing

[552] Retail Coffee / Tea Processing

We then hand searched the following GDA categories to determine whether they were eligible for inclusion, and if so, which category was the most appropriate:

[303] Kiosk - Prepackaged Food Sales (No Food Service Component) = 7 (6 retailers moved to the limited service category, 1 non-permanent location deleted)

[334] Retail Fresh / Vegetable Processing = 6 (4 retailers moved to grocery store category, 2 gift basket retailers deleted)

[348] Retail Acidified/Acid Foods Processing = 2 (category deleted)

[402] Retail Multi-Prod. & Misc. Food Processing = 40 (category deleted, primarily meal preparation services)

[801] Roadside Fresh Vegetable/Fruit Stand = 10 (category deleted)

[802] Farmers Markets = 14 (category deleted)

With a new total of 4,509 we hand searched retailers not categorized by the GDA. One retailer was moved to the *convenience store/pharmacies* category and the remaining retailers were deleted for the following reasons:

Residential = 12

Office building = 4

Farm = 4

Flea market = 1

Shared kitchen = 1

Event venue = 1

Our final GDA dataset consisted of 4,486 retailers.

B. Georgia Department of Public Health (GDPH) data (*limited service* and *full service restaurants*)

<u>Step 1: Geocoding</u>

We geocoded all address data using Google Maps' Geocoding API. There was a 99.9% match rate for the GDPH dataset. Unmatched addresses (n=14) were the result of extraneous data in the address field (e.g. suite numbers). We were able to remove the extraneous information and successfully geocode each address. We identified 20 geocoding errors (0.2%) when plotting the points. The errors resulted from minor inaccuracies in how addresses were listed in the dataset (e.g. NW after a street name rather than SW). We were able to correct these inaccuracies and successfully geocode each address.

Step 2: Remove ineligible retailers

We had three separate datasets for limited service and full service restaurants. GDPH provided data for Cherokee, Clayton, Cobb, Douglas, Fayette, Fulton, Henry and Rockdale counties. DeKalb County Board of Health provide data for DeKalb County and Gwinnett, Newton, & Rockdale County Health Departments provided data for Gwinnett County. We cleaned each dataset separately.

DeKalb County: The full dataset included 2,279 retailers. We began by deleting the following DeKalb County categories deemed ineligible for inclusion:

1. School = 163
2. Mobile Unit = 66
3. Catering = 63
4. Mobile Base = 43
5. Institution = 26
6. Hospital = 21
7. Nursing Home = 15
8. Extended Base = 7
9. Commissary for Bakeries = 1
10. Extended Unit = 3
11. Personal Care Home = 2
12. Feed-a-Kid Vendor = 2
13. Bar only = 2
14. Adult Daycare = 1
15. Senior Center = 1

16. TA-Related FS = 1
17. Base of Operation for Scratch Cuisine = 1
18. Cooking school = 1
19. Jail/Prison = 1

With a new total of 1,859, we hand searched the data for additional ineligible retailers. We deleted 157 additional retailers for the following reasons:

1. Hotel = 50
2. College campus = 15
3. Senior/assisted living = 15
4. Commissary/kitchen/supplier = 10
5. Office building = 10
6. Health care = 9
7. Country/golf/social club = 8
8. Entertainment center = 8
9. Community organization = 5
10. Caterer = 4
11. Mobile unit = 4
12. Event venue = 3
13. Movie theater = 3
14. Performing arts venue = 2
15. Prison/jail/police = 2
16. Religious institution = 2
17. School = 2
18. Community/senior center = 2
19. Arena/stadium = 1

20. Gym/fitness center = 1
21. Museum/zoo = 1

We merged our new total of 1,702 retailers with the Gwinnett and GDPH datasets before searching for duplicates.

Gwinnett County: The full dataset included 2,504 retailers. We began by deleting the following Gwinnett County categories deemed ineligible for inclusion:

1. School = 140
2. Institutional = 16
3. Mobile = 21
4. Catering = 3
5. Temporary = 2

With a new total of 2,322, we hand searched the data for additional ineligible retailers. We deleted 273 additional retailers for the following reasons:

1. Hotel = 58
2. Arena/stadium = 45
3. Senior/assisted living = 44
4. Entertainment center = 22
5. Country/golf/social club = 21
6. Event venue = 12
7. Health care = 10
8. Gym/fitness center = 9
9. School = 9
10. Movie theater = 8

11. Caterer = 7
12. Commissary/kitchen/supplier = 7
13. College campus = 6
14. Office building = 6
15. Community/senior center = 3
16. Performing arts venue = 2
17. Community organization = 1
18. Mobile unit = 1
19. Religious institution = 1
20. Shelter/recovery = 1

We merged our new total of 2,049 retailers with the DeKalb and GDPH datasets before searching for duplicates.

GDPH (remaining 8 counties): The full dataset included 10,626 retailers. We began by deleting the following GDPH categories deemed ineligible for inclusion:

1. School = 645
2. Base of Operation = 295
3. Extended Unit = 294
4. Mobile Unit = 289
5. Long-Term Care = 118
6. Missing = 52
7. Hospital = 25
8. Extended Base = 14
9. Receiving Satellite = 8
10. Receiving or Satellite Kitchens = 3

11. TA-Related FS = 2
12. Incubator = 2
13. Bar only = 1
14. Temporary = 1
15. Other = 1

With a new total of 8,876, we hand searched the data for additional ineligible retailers. We deleted 1,858 additional retailers for the following reasons:

1. Hotel = 406
2. Arena/stadium = 352
3. Airport = 150
4. Country/golf/social club = 100
5. Office building = 88
6. College campus = 75
7. Entertainment center = 65
8. Senior/assisted living = 64
9. Convention center/marketplace = 53
10. Amusement park = 53
11. Caterer = 53
12. Health care = 46
13. Gym/fitness center = 42
14. Religious institution = 41
15. Performing arts venue = 41
16. Movie theater = 31
17. Event venue = 28
18. Community/senior center = 27

19. Community organization = 23
20. School = 24
21. Prison/jail/police = 22
22. Shelter/recovery = 18
23. Museum/zoo = 17
24. Commissary/kitchen/supplier = 16
25. Mobile unit = 10
26. Camp = 5
27. Apartment building = 4
28. Cooking school = 3
29. Seasonal = 1

We merged our new total of 7,018 retailers with the DeKalb and Gwinnett datasets before searching for duplicates.

Step 3: Remove duplicate retailers

10-county Atlanta Regional Commission (ARC) region: The full dataset for all 10 counties included 10,769 retailers, which we searched for duplicates. First, we identified retailers located at the same latitude and longitude with the same name. Once these were removed, we manually searched retailers located at the same latitude and longitude without an exact name match. Locations with very similar names (e.g. Waffle House and Waffle House, Inc.) were considered duplicates. We deleted 247 for a new total of 10,522 retailers. After hand searching, we identified 19 additional retailers for exclusion:

1. Movie theaters with dining = 9
2. College campus = 5
3. Hotel = 3
4. Event venue = 1

5. Office building = 1

Our final GDPH dataset consisted of 10,503 retailers.

Step 4: Categorize retailers

GDPH and DeKalb County: We categorized each retailer into one of two categories: *limited service* retailers or *full-service restaurants*. We sequentially applied three strategies to categorize each retailer. First, we used a list of national limited service retailers and full service restaurants developed by Kelly et al. We also included three additional limited service retailers based on local knowledge (Willy's Mexicana Grill, American Deli, and Jersey Mike's). Second, for the remaining retailers, we applied existing categories that GDPH and DeKalb County use to classify retailers. We grouped the following GDPH/DeKalb County categories under our two broader categories:

Limited service

1. Fast food
2. Drive-through
3. Take-out
4. Carry-out
5. Food court
6. Coffee shop
7. Smoothies
8. Ice cream/Frozen food
9. Bakery

Full-service restaurants

1. Full-service

2. Dine-in
3. 24-hour diner

If retailers could not be classified using one of the above strategies, our third strategy was to use a variable present in all three GDPH datasets called ‘risk type’. This variable indicates whether food is cooked on the premises or whether only pre-cooked/pre-processed foods are served (e.g. ice cream, pre-cooked hot dogs that only require reheating). Retailers that fell into the latter category (risk type 1) were classified as limited service retailers.

Sixty-three retailers (0.6%) could not be categorized using any of the above criteria. We used Google Maps to search for the remaining retailers and classify each one as limited service or full-service based on available images. We classified retailers as limited service if images indicated that food was ordered and paid for at a counter prior to eating. We classified retailers as full-service if images indicated that food was ordered and consumed at a table prior to paying.

Gwinnett County: For Gwinnett County, we were able to use two of the three strategies outlined above: the Kelly et al. list of national limited service retailers and full-service restaurants, and the ‘risk type’ variable. However, the Gwinnett County dataset did not include categories that could be used to classify each retailer. As a result, we were unable to categorize 61% of the retailers located in Gwinnett County. As only 1% of the activity space locations fell within Gwinnett County (i.e. the food environment in Gwinnett County contributed little information to our analyses), we removed the uncategorized retailers from the analytic dataset.