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Rebecca Claire Woodruff Date

Improving Access to Healthy Foods:

Implications for Fruit and Vegetable Consumption and Dietary Quality

By

Rebecca C. Woodruff

Doctor of Philosophy

Behavioral Sciences and Health Education

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MPH, The University of North Carolina at Chapel Hill, 2012

AB, Bryn Mawr College, 2008

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An abstract of

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Abstract

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Disparities in access to healthy foods among rural areas and in neighborhoods with predominantly low-income and racial or ethnic minority residents persist in the United States and may be an important contributor to poor dietary quality and high chronic disease prevalence among these populations. However, research investigating the relationship between access to healthy food retailers and dietary intake has been mixed, and questions remain about the effectiveness of interventions to open new retailers of healthy foods, the mechanisms through which access to healthy food retailers influences dietary behavior, and whether food environments can moderate the efficacy of health promotion interventions. This dissertation explored these questions through three studies. Study one was a systematic review examining the dietary impact of openings of new retailers of healthy foods. Findings indicated that the methodological approaches used in this literature, including study designs, sampling approaches, and outcome measures, ranged widely in rigor. Sub-analyses among the studies that used a repeated measures design indicated that opening a new retailer of healthy foods resulted in short-term improvements in fruit and vegetable consumption among adults who chose to shop at the new retailer, but more rigorous research is needed to confirm these findings. Study two explored food acquisition behaviors as mediators of the association between distance to a primary food store and fruit and vegetable intake among a large national sample of adults. Contrary to expectations, greater distance to a primary food store was weakly associated with increased fruit and vegetable consumption, and this relationship was mediated by greater home inventories of fruits and vegetables, but not shopping frequency. Study three explored to what extent three measures of access to healthy food retailers moderated the efficacy of an intervention to improve dietary quality. Results suggested that limited access to healthy food retailers was associated with poorer dietary quality among the control group, but participation in the intervention may have attenuated this relationship. Results from this dissertation help clarify the role that food retail environments play in influencing dietary behavior and highlight the need for future research focused on food acquisition behaviors as determinants of dietary behavior.

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CHAPTER 1. Introduction

Improving Dietary Intake as a Chronic Disease Prevention Strategy

Two out of every three Americans are currently overweight or obese,[1,2] and chronic diseases, such as heart disease, cancer, and stroke are leading causes of mortality in the United States (US).[3] Dietary intake is an important behavioral determinant of energy balance and healthy weight maintenance,[4,5] and efforts to improve the quality of the typical American diet are a major chronic disease prevention and control strategy in the US.[6,7]

Every five years, the US Department of Agriculture and the Department of Health and Human Services jointly publish *Dietary Guidelines for Americans,* which outlines the federal government's guidance on diet and nutrition.[7] According to these guidelines, healthy diets are rich in fruits and vegetables, whole grains, low-fat dairy products, and lean proteins and limited in saturated and trans fats, sodium, and added sugars.[7] The extent to which an individual person's dietary intake adheres to these guidelines is one of the most commonly used conceptualizations of overall dietary quality.[8-10]

Better dietary quality is associated with reduced weight gain over time,[11] risk of obesity,[12] incident diabetes and coronary heart disease,[13,14] and mortality from cardiovascular disease and cancer.[14,15] A recent meta-analysis of cohort studies estimated that diets of the highest quality are associated with a reduction of all-cause mortality by 22% and mortality from preventable chronic diseases by 15-22%.[14] However, national estimates indicate that the typical American diet does not adhere to federal nutrition guidelines.[16-19]

Large majorities of Americans do not meet the federal government's minimum recommended intake of several nutrient-rich food groups, such as fruits (79.6% ± 1.01),

vegetables (88.7% ± 0.98), whole grains (99.3% ± 0.12).[16] Instead, energy intake disproportionately comes from energy-dense food sources: 95.5% of Americans are estimated to exceed the maximum recommended consumption of solid fats, added sugars, and alcoholic beverages.[16] By one estimate, the only dietary component that Americans consume in sufficient quantities is total protein foods; consumption of all other food groups remains suboptimal.[17] Although multiple trend analyses have indicated modest improvements in overall dietary quality since the late 1990s, it remains poor for the majority of Americans.[17-19]

Fruit and vegetable consumption is an important component of diet quality and efforts to increase fruit and vegetable consumption are an important chronic disease prevention strategy in the US.[6,7] Previous research has shown that greater intake of fruits and vegetables is positively correlated with higher dietary quality and inversely associated with total energy intake.[20] Higher fruit and vegetable intake may also be protective against some forms of cancer[21-26] and cardiovascular disease.[22,27-29] Some evidence indicates that increased consumption of fruits and vegetables may also promote healthy weight maintenance over time,[30-32] possibly by displacing other more energy-dense food sources.[20]

However, fruit and vegetable intake remains below recommended levels. For example, an analysis of Behavioral Risk Factor Surveillance System (BRFSS) data from 2015 indicated that American adults consume fruit and vegetables a median of 1.0 and 1.7 times per day respectively and that relatively few meet fruit (12.2%, 95% CI: 11.2-13.3%) and vegetable (9.3%, 95% CI: 6.1-12.5%) intake recommendations in *Dietary Guidelines for Americans*.[33] According to the most recent estimates from the Nutrition

and Health Examination Survey (NHANES), fruit and vegetable intake is low (estimated 2.4 daily servings, 95% CI: 2.4-2.5),[19] and multiple trend analyses have found no evidence of improvements in intake over time.[19,34,35] These findings suggest that increasing fruit and vegetable consumption at the population level is an important national chronic disease prevention priority.

Current projections indicate that Healthy People 2020 goals for improving dietary quality will not be met.[17] These goals include increasing consumption of fruits, vegetables, and whole grains, and to decreasing consumption of solid fats, added sugars, and sodium.[6] Specifically, for every 1,000 calories consumed, Americans aged 2 years and older should increase their consumption of fruits to 0.93 cup equivalents (2010 baseline: 0.53 cup equivalents), vegetables to 1.16 cup equivalents (2010 baseline: 0.76 cup equivalents), and whole grains to 0.66 ounce equivalents (2010 baseline: 0.34 ounce equivalents).[6] Conversely, for every 1,000 calories consumed, Americans aged 2 years and older should reduce their calories from solid fats to 14.2% (2010 baseline: 16.6%), added sugars to 9.7% (2010 baseline: 15.1%), and should reduce their sodium intake to 2,300 mg (2010 baseline: 3,658 mg).[6]

Socioeconomic Disparities in Dietary Intake

Socioeconomically disadvantaged groups are at particular risk for poor dietary quality. For example, according to 2011-2012 NHANES estimates, 35.7% (95% CI: 29.8-41.9) of adults from the most affluent group (defined as having an income to poverty level ratio ≥3.0) had a diet classified as poor, as compared to 60.6% (95% CI: 56.2-64.9) from the least affluent group (defined as having an income to poverty level ratio <1.3).[19] Additionally, multiple trend analyses have shown differential improvement in dietary quality by socioeconomic status, effectively widening existing socioeconomic disparities

in dietary quality.[18,19] For example, from 2003-2012, the proportion of adults classified as having a poor diet declined most rapidly among the most affluent group (14.8 percentage point decline among adults with income to poverty level ratio of ≥3.0, p<.0001 for trend) as compared to the least affluent group (7.1 percentage point decline among income to poverty level ratio of <1.3, p=.03 for trend), and that these differences were statistically significant (p=.04 for interaction).[19] These findings regarding differential improvements in dietary quality by socioeconomic status have been replicated using different operational definitions of dietary quality.[18]

Similar patterns are evident for fruit and vegetable intake as well. Higher annual household income and educational attainment have been shown to be associated with greater fruit and vegetable intake.[34-39] For example, a recent analysis of NHANES data showed that adults with higher incomes (defined as poverty income ratio of ≥400% poverty threshold) consumed significantly more daily servings of fruits and vegetables as compared to adults with lower incomes (<400% poverty threshold).[39] These results confirm those from a prior analysis, which showed that the most affluent individuals (measured using poverty to income ratio) had 1.65 times the odds of meeting recommended fruit and vegetable intake levels as compared to the least affluent individuals (95% CI: 1.37-1.99).[37] Additionally, individuals with a high school diploma had 1.90 times the odds of meeting recommended fruit and vegetable consumption levels as compared to those with less than a high school diploma (95% CI: 1.62-2.22).[37]

Theoretical Frameworks of Food Environments

The major theoretical frameworks that have been used to characterize food retail environments are discussed below and presented in Figure 1. Although health promotion research has historically focused on individual-level determinants of poor dietary

behavior (e.g., knowledge, cognitions, attitudes, beliefs), in recent years, attention has shifted to the role that environments play in shaping these behaviors. This approach is supported by existing research. For example, a recent review found that psychosocial variables, such as knowledge, attitudes, beliefs, and self-efficacy, accounted for less than 30% of the variability in fruit and vegetable consumption.[40] This suggests that a relatively large proportion of the variability in fruit and vegetable consumption remains unexplained by psychosocial variables and may be explained by higher-order contextual factors.

This emphasis is also consistent with the dominant theoretical frameworks in public health, such as the Social Ecological Model,[41] which have been used to justify focusing on environments as determinants of behavior. According to the Social Ecological Model, health behavior is not simply a function of individual-level risk factors, but also of characteristics of interpersonal relationships, organizational characteristics, community characteristics, and public policy.[41] Story and colleagues have proposed an adapted version of the Social Ecologic Model specifically for dietary behavior, which identifies the following levels of influence: individual factors (e.g., demographic characteristics, cognitions, skills, etc.), social environments (e.g., social support and norms among networks), physical environments (e.g., characteristics of both organizational and community environments), and the policy environment (e.g., regulatory policies.)[42] However, a limitation of the Social Ecological Model is that although it is useful for determining the multilevel influences on health-related behavior, it proposes no specific variables or causal relationships between variables, and does not identify which environmental characteristics are most important. Subsequent work has extended this

model to specify the environmental factors most relevant to the field of dietary behavior (Figure 1). According to these frameworks, the food environment is comprised of multiple built environments,[43] including microenvironments, which refer to characteristics of specific organizations or individual food stores, and macroenvironments, which refer to the composition of food retailers within a geographic area.[44]

Within this body of research, access to healthy food retailers is a commonly used theoretical construct, and is comprised of the following attributes: availability (i.e., the presence of healthy food options within an environment), accessibility (i.e., the distance required to purchase healthy food options), affordability (i.e., the price of food within an environment), acceptability (i.e., the sufficiency and appropriateness of food within an environment), and accommodation (i.e., the ability of a food environment to meet consumers' needs).[45-47] Although the operational definition of healthy food retailers varies widely from study to study, retailers are typically designated as healthy if they fall into one of the following categories, which have been shown to sell a large selection of healthy foods at low cost: supermarkets, large grocery stores, superstores or supercenters, and warehouse clubs.[48,49] These designations are made based off of industry classification codes, including the North American Industry Classification System (NAICS) or Standard Industrial Classification (SIC) codes based on prior research documenting that these categories of retailers typically sell a large variety of healthy food options that are affordably priced.[48,49] Dollar stores, convenience stores, and corner stores are not included in this operational definition of healthy food retailers, as these stores have been shown to sell a more limited selection of healthy food items at higher cost.[48,49] This

approach is limited in that it does not account for variability in the quality and types of food sold in individual stores. However, benefits of using this operational definition of access to healthy foods include that it is an economical and feasible method of approximating access to healthy foods within a community.

Disparities in Access to Healthy Food Retailers

Disparities in access to healthy food retailers may partly explain why the typical American diet is of poor quality, especially among socioeconomically disadvantaged populations. Centers for Disease Control and Prevention (CDC) estimates that 30.3% of census tracts in the US do not have at least one retailer of healthy foods located within their boundaries.[50] Poor neighborhoods, those comprised of predominantly racial and ethnic minority residents, and those located in rural areas are least likely to have access to healthy food retailers.[51-54]

For example, a national analysis found that low-income zip codes had only 75% as many chain supermarkets as median-income zip codes.[52] Additionally, a large multisite cohort study found that supermarkets were 3.3 times as prevalent in high-wealth census tracts relative to low-income census tracts (95% CI: 1.4, 7.9), and 4.3 times as prevalent in predominantly white relative to predominantly black census tracts (95% CI: 1.5, 12.5).[53] Another study conducted in Detroit found that high-poverty census tracts with predominantly African American residents were located 1.1 miles farther from the nearest large grocery store as compared to high-poverty census tracts with predominantly white residents, suggesting a compounding effect of neighborhood wealth and racial composition.[55] Prior research has also shown that census tracts with predominantly African American residents and those with lower median household incomes have a

lower availability of healthy foods, as measured by in-store audits of the foods sold at all retailers within a geographic area.[49]

Access to Healthy Food Retailers as a Determinant of Dietary Intake

Despite the fact that disparities in access to healthy food retailers are well documented,[51] research regarding the associations between access to healthy foods and dietary behavior has been mixed.[45] To date, the vast majority of food environment research has used observational designs among cross-sectional samples.

Most rely on geospatial analysis by obtaining the locations of healthy food retailers from state or municipal records or commercial firms (e.g., Dun & Bradstreet or InfoUSA). Because geospatial analysis is time consuming and resource-intensive, studies using geospatial methods are typically conducted in limited geographic areas. Most studies have focused on urban metropolitan areas (e.g., Boston, New York City, Detroit, New Orleans, Philadelphia, Los Angeles),[54,56-62] though some have focused on rural populations (e.g., rural counties in KY, NC).[63-67]

Commonly used outcome measures include daily servings of fruits and vegetables,[54,56,57,60-62,65,67-69] whether or not dietary guidelines for fruit and vegetable consumption are met,[58,61,62,70] the likelihood of consuming 5 or more servings of fruits and vegetables per day,[66] and various measures of dietary quality.[63,64,71]

Various research groups have defined healthy food retailers differently, with examples of the types of retailers in this category including supermarkets, grocery stores, superstores or supercenters, and warehouse clubs. These store types are often used as proxies for the availability of healthy foods within a geographic area, as they have been shown to sell a larger selection of healthy foods at low prices.[48,49] Convenience stores, dollar stores, and corner stores are not included in the definition of healthy food retailers as these stores

have been shown to sell few healthy food options and at higher prices as compared to the aforementioned store types.[48,49] Although the method of using specific store types as proxies for access to healthy food retailers is imperfect, it remains a feasible methods of identifying communities that likely have limited access to healthy food options.

The two most commonly used measures of access to healthy food retailers include measures of *availability* (e.g., presence, number, and density) and measures of *accessibility* (e.g., proximity to the nearest healthy food retailer).[45] Most studies investigating the availability of healthy food retailers have operationalized this as the presence,[54,57,63,67,72,73] number or density of healthy food retailers[56,58,59,61,68,70,71] within administrative boundaries (e.g., county,[68] zip codes,[58] census block groups,[54,56] census tracts[67,70]) or geographic buffers ranging from 0.5-1 mi around a residential address.[57,61,63,64,71] Studies investigating the accessibility of healthy food retailers typically operationalize the exposure variable as either street network or straight-line distances from the participant's residential address to the newest supermarket.[54,57,60,64,65,73]

Results regarding the relationship between the *availability* of healthy food retailers and dietary behavior are summarized in Table 1. Overall, findings regarding the association between the availability of healthy food retailers and dietary behaviors, such as fruit and vegetable consumption and dietary quality, are mixed. Some, but not all, studies found statistically significant associations between the availability of a healthy food retailer on fruit and vegetable consumption[54,56,63,74] or dietary quality.[71] For example, one study found that the presence of a supermarket or grocery store within a 0.5-mile buffer of the participants' residential address was associated with increased vegetable consumption

(β=3.04, 95% CI: 1.13, 8.17) among Supplemental Nutrition Assistance Program recipients in Kentucky.[63] Another study found that the presence of a large grocery store within a 0.5-mi buffer of the census block group was associated with a 0.69 servings/day increase in F&V consumption (p=.002).[54] A different study found that for each additional supermarket in the census tract, the likelihood of meeting dietary guidelines for fruit and vegetable consumption increased 32% for Black residents (RR=1.32; 95% CI=1.08, 1.60).[70] Individuals with no supermarket within 1 mile of their residential address were 25% less likely to have a healthy diet as compared to participants who had a density of 2.2 supermarkets per square mile near their homes (RP=0.75, 95% CI=0.59, 0.95).[71] However, these results have not been replicated across all studies; many have not found a statistically significant association between the availability of a healthy food retailer and dietary outcomes.[57,58,61,62,64,67,68]

Results regarding the relationship between *accessibility* of healthy food retailers and dietary behavior are summarized in Table 2. Findings from this body of research are also mixed. Two studies found a significant inverse association between distance to the nearest supermarket and fruit and vegetable intake or dietary quality.[64,65] For example, one study of senior citizens in rural Texas found that for each additional mile to the nearest supermarket, participants consumed 0.02 fewer servings of fruits and vegetables per day (p=.002).[65] Another study of pregnant women in North Carolina found that participants who live more than 4.0 miles from a supermarket had lower dietary quality as compared to those living less than 1.99 miles from a supermarket.[64] However, these findings were not replicated across all studies; four studies did not find a statistically

significant association between accessibility to the nearest healthy food retailer and diet.[54,57,60,66]

Initiatives to Increase Access to Healthy Food Retailers

Despite the fact that the relationship between access to healthy food retailers and dietary behavior remains unclear, large-scale health promotion efforts are underway to improve community food environments nationwide. For example, HealthyPeople2020 now includes a developmental objective to "increase the proportion of Americans who have access to a food outlet that sells a variety of foods that are encouraged by the Dietary Guidelines for Americans.[6]" Additionally, public-private partnerships, such as the Healthy Food Financing Initiative, include strategies to access to healthy foods by building new retailers of healthy foods, among other initiatives to improve community food environments.[75] At the state level, the Pennsylvania Fresh Food Financing Initiative funded $73.2 million in loans and $12.1 million in grants from 2004-2010 to assist with financing the development of supermarkets in low-income neighborhoods that lacked access to healthy food options.[76] New York introduced a similar model called the Food Retail Expansion to Support Health (FRESH) program to incentivize the development and retention of neighborhood grocery stores throughout the city using zoning reform and financial incentives.[77] Similar initiatives exist in California and New Orleans as well.[78,79]

In Metro-Atlanta alone, there are numerous examples of new retailers of healthy foods opening to serve communities with limited access to fresh produce. Examples include the Atlanta Mobile Market, a van that distribute fresh produce to underserved communities,[80] and the Fresh MARTA markets, which are freestanding fruit and vegetable stands that sell locally grown fresh produce at public transit stops.[81] Finally, the Boulevard Co-Op and Carver Market are two examples of grocery stores that have

recently opened to serve the residents of the Old Fourth Ward and Westside communities with healthy food options.[82,83]

Research Gaps

Although increasing access to healthy food retailers as a chronic disease prevention strategy is consistent with multiple theoretical frameworks of health promotion, research currently lags behind public health practice. Major gaps in this body of research include that:

Few theoretical frameworks have been developed to guide this area of research.

Although theoretical frameworks have been proposed to justify focusing on food environments as a determinant of dietary behavior, few theories and models have been developed to specify the mechanisms through which neighborhood food environments influence behavior. As a result, this area of research rests on underlying assumptions that have been poorly described and remain largely untested. To date, most studies have estimated the direct effects of various measures of access to healthy food retailers on diet, but relatively few have proposed or empirically tested the mechanisms through which these associations operate. Presumably, food acquisition practices mediate the association between access and diet, such that individuals who live in areas with greater access to healthy food retailers will shop at those retailers more frequently and purchase greater quantities of fruits and vegetables, explaining their higher consumption of these items. However, research is needed to formally test to what extent these variables mediate the association between access to healthy food retailers and diet.

Additionally, with a few exceptions[65,84] little attention has been paid to identifying populations that may be differentially impacted by characteristics of their food environments. For example, are rural populations affected differently than urban

populations? SNAP vs. non-SNAP beneficiaries? Car owners vs. non-owners? Answers to these questions would help focus health promotion programming by identifying the populations that may benefit most from initiatives to improve local food retail environments.

Observational research has largely focused on objectively measured access to healthy foods within residential neighborhoods.

Another gap in this area of research is that most studies have focused on objectively-measured access to healthy food retailers within residential neighborhoods, often operationalized as proximity to the nearest healthy food retailer.[45] However, a recent report by the United States Department of Agriculture suggests that most Americans do not shop at the store located nearest to their residential address.[85] Although distance, travel time, and convenience are likely to be important factors shaping consumer decisions about where to purchase their food, other salient factors may include price, the quality and selection of products, among others.[86-88] Additionally, some consumers may not do their grocery shopping within their residential neighborhoods, but may instead shop at stores located close to their schools, workplaces, or along their daily commute routes.[87] Though some research has focused on access to healthy food retailers within daily activity spaces,[69] this approach remains underutilized and few studies have assessed the impact of transportation options on relationships between access to healthy food retailers and dietary behavior.[89]

Few experimental studies have been conducted regarding the impact that opening new healthy food retailers is likely to have on dietary intake.

The vast majority of research regarding food retail environments has been observational in nature, and few experimental studies evaluating the impact of introductions of new healthy food retailers into communities exist. More rigorous research regarding the effectiveness of this approach for improving dietary behavior is needed in light of the large-scale health promotion efforts to improve community food environments by introducing new retailers of healthy foods into limited-access communities.[75-79] Additionally, although some evaluations of introductions of new supermarkets and grocery stores,[90] farmers' markets,[91] produce stands,[92] and mobile markets exist[93] and have used dietary behavior as outcome variables, no known reviews have summarized this body of research. Such a review would provide a useful resource to methodologically align future research and could be used to compare effect sizes across other categories of interventions to improve dietary behavior, including health education,[94] modifications to in-store food environments,[95] and subsidies/financial incentives.[96]

Few studies have conceptualized the impact of food retail environments in novel ways

In addition to assessing the effect of access to healthy food retailers on diet, characteristics of local food retail environments may shape behavior in other ways. For example, a small but growing body of research has explored to what extent access to healthy food retailers moderates the efficacy of behavioral interventions to improve dietary intake and weight-related outcomes.[97] Research regarding novel conceptualizations of the impact of retail food environments on behavior would advance this body of research and improve our understandings of environments as potential moderators of intervention efficacy.

Dissertation Overview

The purpose of this dissertation is to address some of the aforementioned gaps in the research literature with three studies.

Specific Aim #1: Conduct a systematic review examining the impact of openings of healthy food retailers on dietary behavior. This review will include research articles published in peer-reviewed academic journals, and will focus on documenting the types of retailers that have been evaluated, the settings in which these retailers have been implemented, the methods used to evaluate them, and their impact on fruit and vegetable consumption among adults.

Specific Aim #2: Investigate the relationship between an alternate measure of access to healthy food retailers and fruit and vegetable intake, and assess food acquisition behaviors as mediators of this relationship. Using data from the Emory Prevention Research Center's National Home Environment Survey, this study explores the relationship between self-reported distance to primary food store and fruit and vegetable consumption among a large national sample of consumers who report shopping at supermarkets, grocery stores, superstores, and warehouse clubs. Additionally, we investigate the extent to which frequency of shopping for fruits and vegetables and home inventories of fruits and vegetables mediate this relationship. As an exploratory sub-aim, we investigate whether there is evidence that these relationships are moderated by rurality.

Specific Aim #3: Assess to what extent access to healthy food retailers moderates the efficacy of a health promotion intervention to improve dietary quality. This aim uses data from a randomized trial evaluating Healthy Homes / Healthy Families, a coaching intervention to prevent weight gain among low-income overweight and obese women

living in a predominantly rural region of the state of Georgia. Using geospatial analysis, this study investigates the extent to which three measures of access to a healthy food retailer moderates the efficacy of the intervention for improving dietary quality, as measured by the Healthy Eating Index-2010.[9,10] The measures of access used in this study include distance to the nearest healthy food retailer and the presence and density of healthy food retailers within a 1-mile radial buffer of the participant's residential address.

Combined, these studies will address needed gaps in scientific understanding of how characteristics of food retail environments influence dietary behavior. Specifically, this dissertation aims to identify (1) the extent to which environments can be modified to improve population-level fruit and vegetable consumption, (2) the mechanisms through which access to healthy food retailers influences dietary behavior, and (3) the extent to which characteristics of food environments moderate the efficacy of behavioral intervention to improve dietary outcomes. These studies will inform theoretical frameworks of how environments influence behavior and help understand how these environments can be altered as part of a chronic disease prevention initiatives.

Figures and Tables

Figure 1. Conceptual Model of Physical Environments and Access to Healthy Food Options

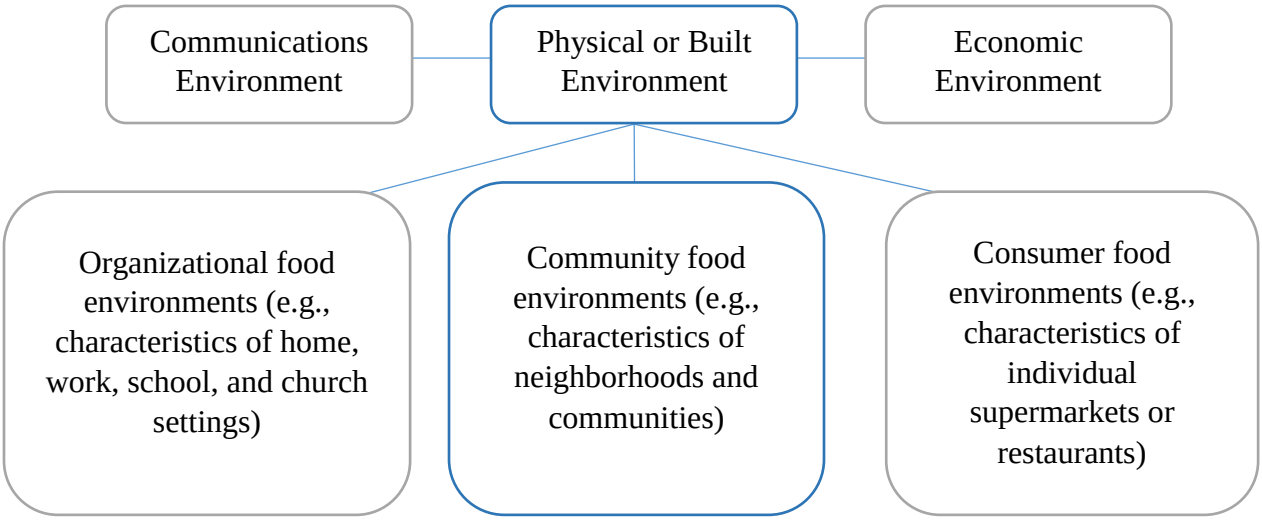

Table 1 Summary of Cross-Sectional Observational Research Studies Examining the Relationship between Availability of Healthy Food Retailers and Dietary Outcomes

Citation	Participants	Exposure	Outcome	Key Results
Group 1: Studies that used F&V intake as main outcome measure				
Gustafson, 2011[67]	N=186 low-income women in NC	Presence of a supermarket in census tract of residence	Daily servings of F&V	No statistically significant association (β=0.12, 95% CI=-0.62, 0.86)
Gustafson, 2013[63]	N=146 SNAP participants Fayette County, KY	Presence of a grocery store/supermarket within 0.5 mile residential buffer	Daily servings of F&V	Store presence associated with increased vegetable consumption (β=3.04, 95% CI: 1.13, 8.17) but not fruit consumption.
Zenk, 2009[54]	N=919 Detroit, MI	Presence of a large grocery store in 0.5-mile buffer of census block group of residence	Daily servings of F&V	Presence of large grocery store in neighborhood associated with 0.69 increase in F&V intake (p=.002).
Bodor, 2008[57]	N=102 New Orleans, LA	Presence of a supermarket within 1,000-meter residential buffer	Daily servings of F&V	Presence of supermarket not significantly associated with F&V intake.
Lucan, 2014[62]	N=4,399 Philadelphia, PA	Presence of a supermarket in census tract + .25-mile buffer	Daily servings of F&V	No significant association (OR=.96, 95% CI: .82-1.11)
Izumi, 2011[56]	N=919 Detroit, MI	Number of food stores selling 5+ kinds of dark green or orange F&V within 0.5-mi buffer from centroid of census block of residence	Daily servings of dark green and orange F&V	Compared to areas with 2+ stores, having 0 stores associated with 0.17 fewer daily servings of dark green and orange vegetables (p=.047).
Mejia, 2015[61]	N=5,185 Los Angeles, CA	Number of large supermarkets within .25, .5, 1, 1.5, and 3-mile residential buffers	Daily servings of fruits and vegetables	No significant associations for any buffer size.
Powell, 2009[52]	N=3,739 National	Density of supermarkets per 10,000 capita within county of residence	Number of times per week F&V consumed	No significant associations.

Citation	Participants	Exposure	Outcome	Key Results
Morland, 2002[53]	N=10,623 ARIC cohort MD, NC, MI, & MN	Number of supermarkets in census tract of residence	Meeting dietary guidelines for F&V consumption	Likelihood of meeting F&V intake guidelines increased 32% for Blacks (RR=1.32; 95% CI=1.08, 1.60) and 11% for Whites (RR=1.11; 95% CI=0.93, 1.32) for each additional supermarket in census tract.
Jack, 2013[58]	N=15,634 New York, NY	Quartiles of healthy food retailer density (supermarkets, F&V markets, health food stores divided by land area) in zip code of residence	Eating 5 or more servings of F&V per day (vs. not)	No significant association (OR=1.12, 95% CI=0.90, 1.38)
Group 2: Studies that used dietary quality as main outcome measure				
Moore, 2008[71]	N=2,384 MESA cohort NC, MD, NY	Density of supermarkets within 1-mile residential buffer	Alternate Healthy Eating Index and Fats & Processed Meats dietary pattern measure	Compared to those with 2.2 supermarkets within 1 mile of home, those with 0 supermarkets were 25% less likely to have a healthy diet (RP=0.75, 95% CI=0.59, 0.95).
Laraia, 2004[64]	N=918 pregnant women in NC	Number of supermarkets within block group of residence or 0.5-mile residential buffer	Dietary Quality Index for Pregnancy (DQI-P)	No significant associations.
Gustafson, 2013[63]	N=146 SNAP participants Fayette County, KY	Presence of grocery store/supermarket within .5 mile residential buffer	Healthy Eating Index	No significant associations.

Table 2. Summary of Cross-Sectional Research Studies Examining the Relationship between Accessibility of Healthy Food Retailers and Dietary Outcomes

Citation	Sample	Exposure & Geographic Unit	Outcome	Key Results
Group 1: Studies that used F&V intake as main outcome				
Zenk, 2009[54]	N=919 Detroit, MI	Distance to nearest supermarket	Daily servings of F&V	No significant association (β=0.056, 95% CI=0.120, 0.638)
Bodor, 2008[57]	N=122 New Orleans, LA	Distance to nearest supermarket	Daily servings of F&V	No significant association for fruit (β=0.445, p=0.642) or vegetable intake (β=-0.94, p=0.930)
Sharkey, 2010[65]	N=582 seniors in rural TX	Network distance to nearest supermarket	Daily servings of F&V	Distance to nearest supermarket was inversely associated with fruit and vegetable intake (β=-0.020, p=0.002).
Caspi, 2012[60]	N=828 low-income housing residents Boston, MA	Network distance to nearest supermarket	Daily servings of F&V	No significant association (p=.22).
Jilcott Pitts, 2013[66]	N=400 women in Pitt County, NC	Network distance to nearest supermarket	Eating 5+ servings of F&V (& BMI – see below)	No significant association (PR=1.02, 95% CI: 0.94, 1.11; p=0.704).
Group 2: Studies that used dietary quality as main outcome				
Laraia, 2004[64]	N=918 pregnant women	Euclidean distance to supermarket (3 level categorical)	Dietary Quality Index for Pregnancy (DQI-P)	Women who lived >4.0 miles from a supermarket had lower dietary quality as compared to women living <1.99 miles from a supermarket.

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CHAPTER 2. The Dietary Impact of Introducing New Retailers of Fruits and Vegetables into a Community: Results from a Systematic Review

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Abstract

Objective: To investigate the potential dietary impact of the opening of new retailers of healthy foods.

Design: Systematic review of the peer-reviewed research literature.

Setting: References published before November 2015 were retrieved from MEDLINE, EMBASE, and Web of Science databases using keyword searches.

Subjects: The outcome of this review was change in fruit and vegetable consumption among adults.

Results: Of 3,514 references retrieved, 92 articles were reviewed in full text, and 23 articles representing 15 studies were included. Studies used post-test only (n=4), repeated cross-sectional (n=4), and repeated measurement designs (n=7) to evaluate the dietary impact of supermarket (n=7), farmers' market (n=4), produce stand (n=2), or produce van (n=2) openings. Evidence of increased fruit and vegetable consumption was most consistent among adults who began shopping at the new retailer. Three of four repeated

measurement studies found modest, albeit not always statistically significant, increases in fruit and vegetable consumption (range 0.23-0.54 servings per day) 6-12 months after baseline. Dietary change among residents of the broader community where the new retailer opened was less consistent.

Conclusions: The methodological quality of studies, including research designs, sampling methods, follow-up intervals, and outcome measures, ranged widely. Future research should align methodologically with previous work to facilitate meta-analytic synthesis of results. Opening a new retailer may result in modest short-term increases in fruit and vegetable consumption among adults who choose to shop there, but the potential longer-term dietary impact on customers and its impact on the broader community remains unclear.

Introduction

Social ecological models of health suggest that community food environments must be structured to support healthy eating behaviors to effectively prevent chronic disease.[1-4] However, a growing body of research has documented disparities in access to healthy foods throughout the United States (US).[5,6] Neighborhoods with predominantly low-income and racial and ethnic minority residents tend to have limited access to retailers of healthier food options, such as full-service supermarkets,[7,8] and are instead disproportionately served by retailers of calorically-dense processed foods, including fast food outlets.[9]

A growing focus on increasing access to healthy foods by opening new retailers in underserved communities is reflected in both national public health objectives and large-

scale healthy food financing initiatives. For example, Healthy People 2020 includes an objective to increase the proportion of Americans who have access to a food outlet that sells foods recommended by federal dietary guidelines.[10] In 2010, the US Departments of Agriculture, Treasury, and Health and Human Services announced the Healthy Food Financing Initiative, which funds the development of new retailers of healthy foods in underserved communities throughout the country.[11] Additional public-private partnerships, such as the Pennsylvania Fresh Food Financing Initiative, the New York Fresh Retail Expansion to Support Health (FRESH) program, the California FreshWorks fund, and the New Orleans Fresh Food Retailer Initiative,[12-15] are emerging as models for improving local food environments. Among other activities, these initiatives incentivize the development of supermarkets and grocery stores in limited-access neighborhoods through zoning reforms, loans, and grants.

Introducing new retailers of healthy foods into limited-access communities is an intuitively appealing intervention strategy, and although multiple evaluations of such initiatives have been published, no known systematic reviews have synthesized this body of research. This systematic review aims to answer the following research questions: 1) What types of retailers of fruits and vegetables have been evaluated and in what settings?; 2) What methods have been used to evaluate these initiatives?; and 3) To what extent have these initiatives impacted fruit and vegetable consumption among adults? Fruit and vegetable consumption among adults was identified as the outcome of interest because this was a commonly used outcome in relevant studies, as well as the broader epidemiologic literature.[6]

Methods

References were retrieved from MEDLINE, EMBASE, and Web of Science databases from inception through November 2015 using a search strategy adapted from a previous systematic review about spatial access to food retailers and diet.[6] English-language references that contained at least one keyword related to the following three domains were retrieved: 1) food retailers (food retail*, food store*, food outlet*, grocer*, supermarket*, farmers market*, farm stand), 2) the environment (access*, availab*, afford*, environment*, loca*, neighborhood*, neighbourhood*, communit*, urban, or rural), and 3) diet (diet, fruit*, vegetable*, nutriti*, consum*, intake).

Two investigators (RCW & IGR) identified candidate articles by independently reviewing the titles of all references for eligibility, referring to the abstracts for additional detail when a decision could not be made based on the title alone. References were excluded if they: 1) were not about the general topic area of access to healthy foods as a determinant of dietary behavior; 2) were not about an initiative intended to increase access to healthy foods; or 3) were not about the introduction of a new retailer of healthy foods into a community. Additional references were identified by hand-searching the bibliographies of the candidate articles and entering their bibliographic information into Google Scholar to identify more recent articles that had cited them.

Once the pool of candidate articles was finalized, all were reviewed in full text. In instances in which multiple publications resulted from the same parent study (e.g., a baseline paper describing the retailer and one or more outcome evaluations), we grouped articles by parent study and determined eligibility at the study-level. Studies were excluded if they were found to meet the exclusion criteria described previously, if the evaluation did not include change in fruit and vegetable consumption as an outcome, or if

it focused exclusively on dietary change among children. Studies that focused exclusively on children were excluded, as the causal mechanism through which the opening of a new retailer of healthy foods would impact diet was expected to differ for this group.

The data abstraction form was developed based on the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement and piloted with a sample of articles. Two investigators (RCW & IGR) independently abstracted the following information from all articles included in the review: bibliographic information, key characteristics of the retailer described in the article (e.g., type, location, date opened, setting, population served, etc.), the methods used to evaluate the retailer (e.g., sampling methods, sample size, data collection procedures, outcome measures, etc.), and its impact on fruit and vegetable consumption; discrepancies were resolved by consensus. For studies that used repeated measurement designs, mean differences in fruit and vegetable consumption were the principal summary measure. Nine corresponding authors were contacted by email for additional information about the methods or results (89% response rate).

Studies were the unit of analysis for this review. Due to the heterogeneity in methods used, meta-analysis was not possible. Analysis involved organizing studies according to the type of evaluation design used and using descriptive statistics, including frequencies and percentages, to describe the types of retailers that were assessed, the methods used to evaluate them, and change in fruit and vegetable consumption. In many cases, the number of references exceeds the number of studies because multiple publications resulted from individual studies.

Results

Of the 5,657 references retrieved through keyword searches, 3,514 were unique articles and 3,437 were excluded based on the title/abstract review (Figure 2). The remaining 77 candidate articles and 15 additional articles identified through hand-searching were reviewed in full text to assess eligibility. Of these, 69 articles were excluded. The most common reasons for exclusion were that the article was not a peer-reviewed original research article (i.e., was an opinion piece, editorial, letter to the editor, conference abstract, review, government report, or policy description; n=32); was not about the opening of a new retailer of healthy foods (e.g., was focused on a grocery delivery service, community-supported agriculture program, food policy council, or farm; n=15); or did not assess change in fruit and vegetable consumption among adults as part of the evaluation (n=22). The 22 articles in this latter category commonly reported implementation or process evaluation data (e.g., sales volume, demographic characteristics of shoppers, satisfaction with the retailer, etc.) or changes to other non-dietary outcomes (e.g., customers' shopping patterns, access to healthy foods, etc.). This review focuses on the remaining 23 articles, which represented 15 unique studies.

Description of Retailers & Settings

As shown in Table 3, the types of retailers assessed included supermarkets and grocery stores (n=7),[16-30] farmers' markets (n=4),[31-34] fruit and vegetable stands or markets (n=2),[35,36] and mobile produce vans (n=2).[37,38] Supermarkets and grocery stores tended to be subsidized through public-private partnerships, including the Healthy Food Financing Initiative (n=2)[19,22,23] and the New York Food Retail Expansion to Support Health (FRESH) initiative (n=1),[20,21] or were aligned with broader corporate initiatives to

promote economic development or open supermarkets in deprived areas (n=2).[24-27,29,30] The smaller retailers, such as farmers' markets, fruit and vegetable stands or markets, and mobile produce vans, tended to report community involvement in planning or operating the retailer, including having a community advisory board, collaborating with other local organization to implement the retailer, or that the project used a community-based participatory approach (n=7).[31-36,38]

Most of the retailers were located in low-income and/or economically deprived communities (n=13)[16-30,32,33,35-38] that had limited access to healthy foods (n=12)[16-31,33-36] in either the United States (US; n=11),[19-23,28-33,35-37] the United Kingdom (UK; n=3),[16-18,24-27,38] or Australia (n=1).[34] Many studies also described the communities in which the new retailer opened as comprised of predominantly racial or ethnic minority residents (n=7).[19-23,29-33] Most retailers were located in general community settings (n=11),[16-31,33,34,38] though some farmers' markets, fruit and vegetable stands, and mobile produce retailers operated at local community organizations (n=3),[35-37] residential housing complexes (n=2),[35,37] and health centers (n=1).[32]

Evaluation Methods

A variety of methods were used to evaluate the impact of the retailer on fruit and vegetable intake. Retailers were evaluated using post-test only designs (n=4),[28,33-35] repeated cross-sectional designs (n=4),[20,21,29-31,38] and repeated measurement designs (n=7; Table 3).[16-19,22-27,32,36,37] Studies assessed the impact of the retailer on fruit and vegetable consumption approximately six months (n=7),[24-28,31,32,35-37] one year (n=5),[16-23,29,30] or two years (n=2)[33,38] after the retailer opened, or at multiple follow-up intervals.[33]

Eight studies used convenience sampling,[20,21,28,31,33-35,37,38] and six used probability sampling methods.[16-19,22,23,29,30,32,36] The sampling method could not be determined for one study.[24-27] Six studies sampled shoppers at the new retailer [31,33-35,37,38] and three sampled residents of the neighborhood where the new retailer opened.[24-28,36] An additional five studies sampled from both residents of the neighborhood where the new retailer opened and a comparison neighborhood that did not receive a new retailer.[16-23,29,30] One study sampled patients at a health clinic where the retailer was located.[32] Sample sizes ranged widely.

Outcome measures included retrospective items asking participants to what extent their fruit and vegetable intake changed over time (n=4),[28,33-35] 2-item screeners assessing usual daily intake of fruits and vegetables (n=3),[19,31,38] brief fruit and vegetable intake screeners or food frequency questionnaires (n=6),[16-18,20,21,29,30,32,36,37] or dietary recalls (n=3).[20-27] One study used multiple methods of assessing fruit and vegetable intake.[20,21]

Post-Test Only Designs

Methodological Overview

Four studies used post-test only designs to assess the dietary impact of the new retailer (**Table 3**). In these studies, cross-sectional surveys were administered to participants four months to two and a half years after the opening of the retailer.[28,33-35] All studies focused on dietary change among a convenience sample of adults who were either shoppers at the retailer[33-35] or lived in the neighborhood where the new retailer opened for business.[28] All of these studies used a retrospective approach to measure change in fruit and vegetable intake by asking participants to report changes in fruit or vegetable consumption as a result of shopping at the retailer[33-35] or generally within the past year.[28]

Change in Fruit and Vegetable Intake

Of the studies that surveyed shoppers at the retailer, most respondents reported that they were eating more fruits and/or vegetables at the time of the survey.[33-35] For example, of 100 shoppers at a farmers' market in Carnarvon, Western Australia who were surveyed approximately two and a half years after its opening, 71% reported that they were eating more fruits and vegetables since they started shopping there.[34] A survey of 100 returning customers who were surveyed approximately four months after the opening of a fruit and vegetable stand in Cobb County, Georgia, US, reported that they were eating more vegetables (65%) and fruit (55%) as a result of the market.[35] Another survey administered to shoppers at two farmers' markets in Los Angeles, California, US between five months and two years after the markets opened reported that 97-98% agreed or strongly agreed that they were eating more fruits and vegetables as a result of the market.[33] By contrast, the one study that assessed the impact of a new grocery store that opened in an unnamed city in California, US among on the dietary behaviors of residents of the neighborhood where it opened (regardless of whether participants shopped there) found smaller changes in fruit and vegetable consumption. Relatively few respondents who lived two miles from a new grocery store reported increased vegetable (10.3%) or fruit (9%, N=73) consumption over the previous year.[28]

Repeated Cross-Sectional Designs

Methodological Overview

Four studies used repeated cross-sectional surveys at baseline and follow-up to assess the dietary impact of the new retailer (Table 3). Two studies used a convenience sample of market shoppers;[31,38] one used a random sample of households with landlines

located within 2,000 meters of the store site and a nearby comparison neighborhood;[29,30] and another recruited participants from busy intersections in the neighborhood where the retailer opened, as well as a nearby comparison neighborhood.[20,21] Measurement approaches included using a two-item fruit and vegetable intake screener;[31,38] the Behavioral Risk Factor Surveillance System (BRFSS) screener,[29,30] or a combination of a brief screener and a single 24-hour dietary recall.[20,21]

Change in Fruit and Vegetable Intake

Results from studies in this category were difficult to summarize due to the heterogeneity in methodological approaches. For example, one evaluation of a farmers' market in Nashville, Tennessee, US found that shoppers sampled at one- and two-months follow-up reported higher levels of fruit and vegetable consumption relative to a different sample of shoppers sampled at baseline.[31] However, these results were reported graphically, and no estimates of mean intake were presented to quantify the difference in mean intake between the samples over time.[31] A different study of a convenience sample of shoppers at a mobile produce van in the UK found that those sampled at follow-up reported higher mean fruit and vegetable intake at follow-up than the baseline sample (mean difference=1.16 portions, 95% CI: 0.83-1.48, $p<.0001$).[38]

Two studies assessed community-level dietary change among residents of the neighborhood that received the new retailer relative to those who lived in a comparison neighborhood.[20,21,29,30] One of these studies conducted telephone surveys before and 12 months after a grocery store opened in Flint, Michigan, US among a random sample of households located within 2,000 meters of the new store and those located in a comparison neighborhood. This study found that mean intake of fruits and vegetables

was the same among the baseline and follow-up samples in the intervention neighborhood (mean intake=2.6 among samples at both time points), although mean intake was higher among the comparison neighborhood residents in the follow-up sample relative to the baseline sample (mean intake=2.5 at baseline, mean intake=2.9 at follow-up).[29,30] Information about the precision and statistical significance of these estimates are unavailable.

Another study conducted surveys among adults recruited from busy intersections located in a neighborhood that received a new supermarket and a comparison neighborhood in the Bronx, New York City, US.[20,21] Surveys were administered at baseline, 1-5 months, and 13-17 months after the supermarket opened, and included two different methods of assessing fruit and vegetable intake. Results from the brief fruit and vegetable intake screener indicated that among both intervention and comparison neighborhood residents, mean fruit and vegetable intake was highest at baseline relative to either follow-up time point (e.g., mean change in vegetable consumption=-0.1 daily servings among intervention neighborhood sample vs. 0.0 among comparison neighborhood sample). Results from the 24-hour dietary recalls showed a different pattern of higher fruit and vegetable consumption at follow-up relative to baseline in both groups, though greater improvements among those sampled from the comparison community (e.g., mean change in vegetable consumption of 0.21 daily servings among intervention neighborhood sample vs. 0.58 daily servings among comparison neighborhood sample).[20,21]

Repeated Measurement Designs

Methodological Overview

Seven studies used repeated measurements to assess the dietary impact of the new retailer (Table 3). All of these studies collected data from participants at baseline, and at either one (n=6)[16-19,22-26,36,37] or two (n=1)[32] follow-up time points. The majority of these studies used probability sampling methods to recruit participants,[16-19,22,23,32,36] though one used convenience sampling methods[37] and the approach used by another could not be determined.[24-27] One study recruited shoppers at the new retailer,[37] two recruited residents of the neighborhood where the new retailer opened,[24-26,36] and three recruited residents of both the intervention neighborhood and a nearby comparison neighborhood.[16-19,22,23] One study recruited patients from the clinic where the new retailer opened for business.[32] Studies in this category measured change in fruit and vegetable consumption using a two-item screener asking about usual intake of fruits and vegetables per day (n=1),[19] brief screeners or food frequency questionnaires (e.g., BRFSS,[37] the National Cancer Institute Fruit and Vegetable Screener,[32,36] or the Block Food Frequency Questionnaire;[16-18] n=4), a 7-day food diary (n=1),[24-26] or multiple 24 hour dietary recalls (n=1).[22,23]

Change in Fruit and Vegetable Intake

With one exception,[19] all studies in this category reported mean within-person change in fruit and vegetable intake from baseline to follow-up. Depending on the sampling strategy used, these results could be presented in three ways: 1) change in fruit and vegetable intake among *shoppers at the new retailer*, 2) change in fruit and vegetable intake among *residents of the neighborhood where the new retailer opened*, or 3) *the difference in differences* comparing mean change in fruit and vegetable intake among residents of the intervention vs. comparison neighborhood (Table 4).

Of the five studies that reported *change in fruit and vegetable intake among shoppers at the new retailer*, most reported modest, albeit not always statistically significant, increases in mean intake (n=4),[24-26,32,37] although one study reported a small decrease.[22,23] For example, one study of 43 shoppers at a mobile produce van in Troy, New York, US reported a statistically insignificant 0.45-serving increase in daily fruit and vegetable intake six months after the van expanded its route to serve additional stops (95% CI: -0.23, 1.14).[37] Another study of 41 diabetic adults who shopped at a farmers' market in a health clinic in rural South Carolina, US reported a statistically insignificant 0.54-serving increase in fruit and vegetable intake five months after it opened (95% CI: -1.14, 2.23).[32] Another study of 276 shoppers at a new supermarket in Leeds, UK reported a statistically significant 0.23-portion increase in fruit and vegetable intake 6-7 months after it opened (p=.034).[24-27] However, a study of 368 shoppers at a new supermarket in Philadelphia, Pennsylvania, US reported a statistically insignificant -0.32-serving decrease in intake 7-14 months after it opened.[22,23]

Results were less consistent among the four studies that assessed *change in intake among residents of the neighborhood where the new retailer opened for business*. For example, one study of 615 residents found essentially no change in fruit and vegetable consumption 6-7 months after the opening of a new supermarket in their neighborhood in Leeds, UK (mean difference=0.04 portions per day).[24-27] However, two studies found evidence of modest, but not statistically significant, increases in fruit and vegetable intake. The first reported a statistically insignificant 0.42-serving increase in daily intake among a probability sample of 61 adults who lived within 0.5 miles of a new fruit and vegetable stand in Austin, Texas, US two months after it opened.[36] The other study found

a 0.29-portion increase among a probability sample of 191 adults who were the main food shoppers for their homes and lived in a Glasgow, UK neighborhood where a new supermarket was opened at 11 months follow-up (p=.07).[16-18] In contrast to these results, a study that included a probability sample of 571 adults living in a neighborhood in Philadelphia, Pennsylvania, US where a new supermarket opened, reported a statistically significant 0.27-serving decrease in fruit and vegetable consumption at 6 months follow-up (SE=0.08, p<.001).[22,23]

Two studies reported *difference-in-differences* comparing change among residents of the neighborhood where the new retailer opened, relative to change among residents in a comparison neighborhood. These studies evaluated supermarket openings in Pittsburgh, Pennsylvania, US[22,23] and Glasgow, UK.[16-18] In both instances, results were the opposite of what was expected and indicated either greater increases in fruit and vegetable intake among the comparison neighborhood residents (difference-in-differences: -0.15)[16-18] or smaller decreases in fruit and vegetable intake among comparison neighborhood residents (difference-in-differences: -0.14).[22,23]

Discussion

Most studies included in this review focused on recent openings of healthy food retailers in low-income communities with limited access to healthy foods. The methodological approaches to evaluating these initiatives, including the research designs, sampling approaches, follow-up intervals, and outcome measures, varied widely. Though all study designs were limited in their ability to causally attribute any observed change in fruit and vegetable consumption to the opening of the retailer itself, evaluations of supermarket and grocery store openings tended to use more rigorous study designs (e.g.,

two-group repeated measure or repeated cross-sectional designs with larger representative samples), while evaluations of farmers' markets, fruit and vegetable stands, and mobile produce vans tended to use weaker designs (e.g., post-test only designs with smaller convenience samples).

Across study types, results suggest that the dietary impact of the new retailer may be greatest among adults who choose to shop there. For example, three out of four repeated measurement studies of shoppers at the new retailer found modest increases in fruit and vegetable consumption, ranging from 0.23-0.54 daily servings at 6-12 months follow-up.[24-27,32,37] Although most of these effect sizes did not reach statistical significance, two reported small sample sizes calling into question whether they were powered to detect dietary change of this magnitude. These effect sizes are similar in magnitude to those reported by a systematic review of behavioral interventions to increase fruit and vegetable intake,[39] and prior research has documented that even small increases in fruit and vegetable intake may be related to reductions in energy density.[40] Additionally, results from all three post-test only designs that surveyed shoppers at the new retailer found that relatively high proportions of shoppers reported that they were eating more fruits and vegetables since starting to shop there (55%-98%).[33-35]

The impact of the opening of a new retailer on fruit and vegetable consumption among the broader community of residents of the neighborhood where the retailer opened was less clear. Studies that used either repeated measurement or repeated cross-sectional designs found no evidence of change,[24-27,29,30] modest increases,[16-18,20,21,28,36] or decreases[20-23] in fruit and vegetable consumption. The variability in results may be explained in part by the heterogeneity in methodological approaches used, including

eligibility criteria and methods used to sample intervention neighborhood residents. Those that also sampled from a comparison neighborhood were unable to detect a significant difference in mean change in fruit and vegetable consumption between the two groups.

We are limited in our ability to comment on differential dietary impact by retailer type due to the methodological heterogeneity among studies included in this review. However, evaluations of one category of retailer – supermarkets – tended to have the most methodological consistency, with four out of five studies employing a repeated measurement design. These studies found mixed results regarding the impact of the new retailer on fruit and vegetable consumption among shoppers,[22-27] residents of the intervention community,[16-18,22-27] and differences between residents of intervention and comparison communities.[16-18,22,23] Although previous reviews have documented systematic disparities in access to supermarkets among many neighborhoods throughout the US,[5] research regarding the causal links between access to supermarkets and improved dietary intake is inconclusive.[6] In light of the large-scale initiatives focused on policy, systems, and environmental changes to improve community retail food environments, many of which focus on introducing supermarkets into low-income communities, more rigorous research with greater methodological consistency is needed regarding the impact of supermarkets on dietary behavior.[12-15,41]

A strength of this review is that it is the first to our knowledge to summarize the state of scientific knowledge regarding the potential dietary impact of opening new retailers of healthy foods within a community. Limitations of this review include potential publication bias and incomplete retrieval of relevant articles from the keyword search

strategy. Additionally, most studies evaluated the dietary impact of the opening of new retailers within low-income neighborhoods with limited access to healthy foods in the US. The extent to which these findings would generalize to other geographic contexts (e.g., developing countries, non-Western contexts, etc.) is unknown. Additionally, this review focused exclusively on the impact of these retailers on fruit and vegetable intake among adults. The impact on fruit and vegetable intake among children or on other outcomes relevant to dietary behavior or chronic disease prevention remains unknown. Many articles that were considered for[42,43] or included in this review,[20-23] or have been published since[44-46] assessed other outcomes of interest, including area-level access to healthy foods, change in other dietary behaviors (e.g., change in total energy intake, dietary quality, or consumption of specific food groups), or body mass index. These may be outcomes of potential interest for future reviews.

Results from this review suggest that that opening a new retailer of healthy foods in limited-access communities may be an appropriate strategy to improve short-term fruit and vegetable intake among adults who choose to shop there, although more research is needed to confirm these findings and to understand the potential impact of this approach on the broader community and/or over longer periods of time. Interventions that focus on other structural interventions, such as improving the in-store environments of existing retailers may be a more appropriate strategy for improving population-level dietary behavior.[47,48] Limitations of this body of research include a reliance on pre-experimental or quasi-experimental designs with limited ability to establish causality, potentially underpowered studies reliant on small sample sizes, and the use of a range of outcome measures and follow-up intervals that prevents meta-analytic synthesis of results.

Recommendations for future research include designing adequately powered studies that are methodologically aligned with those of previous work to facilitate comparisons and summary of these initiatives and strengthen the evidence base regarding this potential dietary impact of this approach to improving community food environments.

Figures and Tables

Figure 2. Flow Diagram Depicting Article Selection for Inclusion in Systematic Review

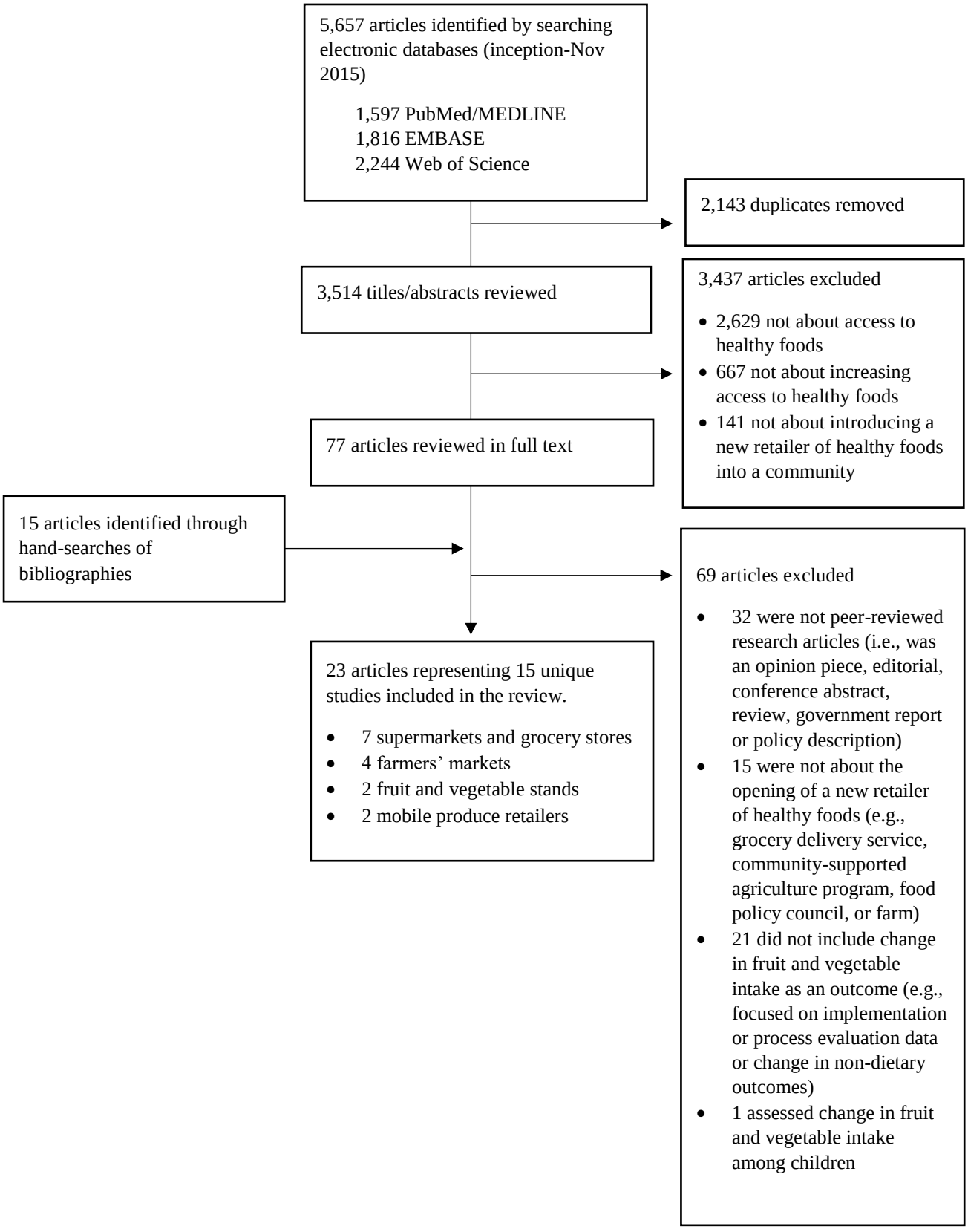

Table 3. Methodological Summary of Evaluations of the Opening of a Retailer of Healthy Foods on Fruit and Vegetable Intake among Adults (N=15)

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
Post-Test Only (n=4)	(Woodruff et al, 2016) [35]	Fruit and vegetable stand 2014 Cobb County, Georgia, US	Convenience sample of returning market shoppers aged 18+ (N=100, 99%)	Self-administered surveys 4 months after market opening	2-item retrospective measure	65% reported eating more vegetables, 55% reported eating more fruit as a result of shopping at the market
	(Ruelas et al, 2012) [33]	Farmer's markets 2007 Los Angeles, California, US	Convenience sample of market shoppers aged 18+ (N=415 at one location, n=1,375 at second location, NR)	Surveys administered 5 months after market opening at one location and 2 years after opening at second location	Single-item retrospective measure	97-98% agreed or strongly agreed that they eat more fruits and vegetables because of the market
	(Payet et al, 2005) [34]	Farmers' market 2001 Rural community near	Convenience sample of market shoppers aged 18+ (N=100, 80.6%[a])	Surveys administered 2 years and 4 months after market opening	Single-item retrospective measure	71% reported eating more fruits and vegetables since started shopping at the market

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
		Carnarvon, AUS				
	(Wang et al, 2007) [28]	Grocery store 2004 Northern California, US	Convenience sample of adults aged 18+ who were the primary grocery shoppers for their homes and lived ~2 mi from the store (N=78, NR)	Surveys administered 6 months after store opening	4-item measure assessing frequency of fruit and vegetable consumption currently and last year	10% reported an increase in fruit consumption, 9% reported an increase in vegetable consumption over the previous year[a]
Repeated Cross-Sectional (n=4)	(Freedman et al, 2007) [31]	Farmers' Market 2006 Nashville, Tennessee, US	Convenience sample of market shoppers	Surveys administered at baseline (n=29), mid-way through the season (n=15), and at the end of the season (n=16)	2-item screener adapted from Youth Risk Behavior Surveillance System	Results are reported graphically, but suggest a pattern of greater fruit and vegetable consumption among follow-up sample relative to baseline sample.
	(Jennings et al, 2012) [38]	Mobile fruit and vegetable van 2008 Great Yarmouth and Waverly, UK	Convenience sample of shoppers (N=255; 62%)	Surveys administered at baseline and 2 years after van began operating	2-item screener measuring portions consumed per day	1.16-portion increase in mean fruit and vegetable consumption (95% CI: 0.83-1.48, p<.001)

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
	(Sadler et al, 2013) [29,30]	Grocery store 2010 Flint, Michigan, US	Probability sample of adults aged 18+ who were the primary grocery store for their homes and either lived within 2,000 m of the store or in a nearby comparison neighborhood (n=150-200 per time point, 15% response rate)	Interviewer-administered surveys at baseline and 12 months after store opening	Behavioral Risk Factor Surveillance System (BRFSS) screener	0.0-serving change in fruit and vegetable consumption among intervention residents[a] 0.4-serving increase among comparison neighborhood residents[a]
	(Elbel et al, 2015) [20,21]	Supermarket 2011 South Bronx, New York, US	Convenience sample of adults aged 18+ (approximately n=1,300 per time point, NR)	Intercept surveys and dietary recalls administered at baseline, 1-5 months and 13-17 months after store opening.	24 hour dietary recall and the Eating and Physical Activity Survey	<u>24 Hour Dietary Recall Results</u>: 0.05-unit increase in fruit and 0.21-unit increase in vegetable consumption at final follow-up Difference in differences: 0.10 for fruit and 0.32 for vegetable consumption <u>Screener Results</u>:

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
						0.2-unit increase in fruit consumption and 0.1-unit increase in vegetable consumption at final follow-up Difference in differences: 0.1 for fruit and 0.0 for vegetable consumption Note: No results reached statistical significance
Repeated Measurement (n=7)	(Abusabha et al, 2011) [37]	Mobile fruit and vegetable van 2007 Troy, New York, US	Convenience sample of shoppers aged 55+ who lived at the senior housing complex served by the van (N=43, 54% at follow-up[a])	Surveys administered at baseline and 6 months after the van began serving the senior housing complex	5-item screener adapted from BRFSS	0.45-serving increase in total fruit and vegetable intake (95% CI: -0.23, 1.14; p=.188)
	Freedman et al, 2013) [32]	Farmers' market 2001	Probability sample of adult patients at the health clinic where the farmers'	Interviewer-administered surveys at baseline, 2,	19-item screener adapted from the National	0.54-serving increase in total fruit and vegetable intake

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
		Rural county in South Carolina, US	market operated who had a diagnosis of diabetes (N=44, NR)	and 5 months after the market opening	Cancer Institute Fruit and Vegetable Screener (NCI FVS)	at 5-month follow-up (95% CI: -1.14, 2.23; p=0.52)
	(Evans et al, 2012) [36]	Fruit and vegetable stand 2010 Austin, Texas, US	Probability sample of adults aged 18+ who lived within 0.5 miles of market recruited through door-to-door household sampling (N=61, 66% at follow-up)	Interviewer-administered surveys at baseline and 2 months after the market opened	7-item screener adapted from the NCI FVS	0.42-serving increase in total fruit and vegetable intake among intervention community residents (SD=2.49; p=0.210)
	(Wrigley et al, 2002-4 & Gill et al, 2014) [24-27]	Supermarket 2000 Leeds, England, UK	Sample of adults who were responsible for domestic food arrangements for the household and who lived in the neighborhood where the supermarket opened (N=615, 61% at follow-up)	Self-administered food consumption diary at baseline and 6-7 months after the store opening	7-day food consumption diary	0.23-serving increase in fruit and vegetable intake among residents who began shopping at the new retailer (p=.034) 0.04-serving increase in fruit and vegetable intake in intervention

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
						community residents[a]
	(Cummins et al, 2005-8) [16-18]	Supermarket 2001 Glasgow, Scotland, UK	Probability sample of adults aged 16+ who were the main food shopper for their homes and who live in the neighborhood where the supermarket opened of a comparison community (N=412, 68% at follow-up)	Self-administered postal survey at baseline and 11 months after the store opening	2-item screener assessing usual fruit and vegetable intake per day	0.29-portion increase in fruit and vegetable intake in the intervention community (p=.07) 0.44-portion increase in fruit and vegetable intake in the comparison community (p=.003)
	(Cummins et al, 2014) [19]	Supermarket 2009 Philadelphia, Pennsylvania, US	Probability sample of adults aged 18+ who lived near the new supermarket or were residents of a neighboring community recruited through random directory listings and random digit dial (N=656, 46% at follow-up)	Interviewer-administered surveys at baseline and 6 months after store opening	22-item screener adapted from Block Food Frequency Questionnaire	-0.16-serving difference between neighborhoods at baseline -0.21-serving difference between neighborhoods at follow-up.

Study Design	References	Retailer, Year Opened, Setting	Sample Description (Sample Size, Response Rate)	Data Collection	Outcome Measure	Results
						Difference in differences: -.05 (NS)
	(Dubowitz et al, 2015) [22,23]	Supermarket 2013 Pittsburg, Pennsylvania, US	Probability sample of adults aged 18+ who were the primary food shopper for their household and lived in the neighborhood where the supermarket opened or a comparison neighborhood recruited through door-to-door sampling (N=831, 65% at follow-up)	Interviewer-administered surveys at baseline and 7-14 months after the store opening	Two 24-hour dietary recalls administered 7-14 days apart	-0.32-serving change among adopters of the new retailer (NS) -0.27-serving change among residents of intervention community (SE=0.08, p<.001) Difference in differences (intervention vs. comparison neighborhood residents): -0.14 (NS)

Abbreviations: US=United States, AUS=Australia, UK=United Kingdom, NR=Not Reported

[a] Calculated by hand using information provided in the article.

Table 4. Effect Sizes of the Impact of the Opening of a New Retailer of Healthy Foods on Within-Person Change in Fruit and Vegetable Consumption among Adults (n=6)

Citations	Retailer	Country	Outcome Measure	Sample	Mean difference	95% CI or Statistical Significance	Follow-Up Interval
Change in Fruit and Vegetable Intake Among Adult Shoppers at the Retailer							
(Abusabha et al, 2011) [37]	Produce van	US	BRFSS screener	43 adults ages 55+	+ 0.45 servings	95% CI: (-0.23, 1.14)	6 months
(Freedman et al, 2013) [32]	Farmers' market	US	NCI FVS	41 adults with diagnosis of diabetes	+ 0.54 servings	95% CI: (-1.14, 2.23)	5 months
(Wrigley et al, 2002) [24-27]	Supermarket	UK	7 day food diaries	276 adults	+ 0.23 portions	p=.034	6-7 months
(Dubowitz et al, 2015) [22,23]	Supermarket	US	Two 24 hour dietary recalls	368 adults	- 0.32 servings	NS	7-14 months
Change in Fruit and Vegetable Intake Among Adult Residents of Neighborhood that Received New Retailer							
(Evans et al, 2012) [36]	Fruit and vegetable stand/market	US	NCI FVS	61 adults	+ 0.42 servings	SD=2.49, p=0.210	2 months
(Wrigley et al, 2002) [24-27]	Supermarket	UK	7 day food diary	615 adults who were responsible for domestic food arrangements for the household	+ 0.04 portions[a]	NS	6-7 months
(Cummins et al, 2005) [16-18]	Supermarket	UK	2-item screener assessing usual daily intake	191 adults who were the main food shopper for their homes	+ 0.29 portions	p=.07	11 months

(Dubowitz et al, 2015)[22,23]	Supermarket	US	Two 24-hr dietary recalls	571 adults who were the primary food shopper for their homes	- 0.27 servings	SE=0.08, p<.001	7-14 months
Difference in Change in Fruit and Vegetable Intake Comparing Adult Residents of Intervention vs. Comparison Neighborhood							
(Cummins et al, 2005)[16-18]	Supermarket	UK	2-item screener assessing usual daily intake	412 adults	-0.15[a]	NR	11 months
(Dubowitz et al, 2015)[22,23]	Supermarket	US	Two 24-hr dietary recalls	831 adults who were the primary food shopper for their homes	-0.14	NS	7-14 months

Abbreviations: US=United States, UK=United Kingdom, CI=Confidence Interval, NR=Not Reported, NS=Not statistically significant, SE=Standard error, BRFSS=Behavioral Risk Factor Surveillance System, NCI FVS=National Cancer Institute Fruit and Vegetable Intake Screener

[a] – Result was calculated by hand based on information provided in the article.

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CHAPTER 3. Home Food Inventories and Shopping Frequency as Mediators of the Association between Access to Healthy Food Retailers and Fruit and Vegetable Consumption

Abstract

Introduction: Disparities in access to healthy foods are well-documented and a likely determinant of dietary behavior, but the mechanism through which access to healthy food stores influences diet is poorly understood. This analysis explored the relationship between access to primary food stores and fruit and vegetable consumption and the extent to which frequency of shopping for fruits and vegetables and home inventories of fruits and vegetables mediated this relationship.

Methods: An online survey was administered to a large national sample matched to the US population on age, race/ethnicity, geographic region, and annual household income. Of 4,942 respondents, 3,775 (76.4%) adults who reported some involvement with grocery shopping for their household and primarily shopped at a healthier food retailer were included in this analysis.

Results: Most respondents were white (68%), middle-aged (mean age: 45 yrs), women (57%), and lived in urban or suburban areas (70%). Most reported that they were the primary shoppers for their homes (80%) and that they primarily shopped at large chain grocery stores (55%). Greater distance to primary food store was significantly associated with greater fruit and vegetable consumption (β=.009, 95% CI: .001, .02, p=.03), but explained very little of the variability in the outcome (R^2<1%). Home inventories of fruits and vegetables were a significant partial mediator of this relationship, such that greater

distance was associated with greater fruit and vegetable intake through greater home inventories of fruits and vegetables (indirect effect: β=.02, 95% CI: .001-.03, p=.03). Frequency of shopping for fruits and vegetables was not a statistically significant mediator.

Conclusions: Contrary to expectations, individuals who travel greater distances to their primary food stores report greater fruit and vegetable consumption, presumably because they purchased a greater variety of fruits and vegetables while shopping, thus explaining greater home inventories. It is possible that consumers who eat diets rich in fruits and vegetables seek out stores with a better selection of these products, which are located farther from their homes, but more research is needed to confirm this finding.

Introduction

The typical American diet does not adhere to federal dietary guidelines,[1] and daily fruit and vegetable consumption is particularly low.[2] Recent national estimates indicate that Americans consume fruits and vegetables a median of 1.0 and 1.7 times per day respectively, and few meet recommendations fruit (12.2%) and vegetable (9.3%) outlined in *Dietary Guidelines for Americans*, which are individualized based on age, gender, sex, and physical activity levels.[3,4] These dietary patterns are likely contributors to the high prevalence of overweight, obesity, and preventable chronic disease in the United States.[5,6] Improving dietary quality by increasing fruit and vegetable consumption is an important public health priority.[7]

Disparities in access to healthy foods may partly explain inadequate fruit and vegetable consumption in the United States (US). Supermarkets, grocery stores, supercenters, and

warehouse clubs are often used as markers of access to healthy foods, as these retailers have been shown to carry a larger selection of healthier foods at lower prices compared to convenience stores and other small food stores.[8-11] However, the Centers for Disease Control and Prevention estimates that nearly one-third (30.3%) of census tracts in the US do not have a retailer of healthy foods located within a half mile of their boundaries.[10] Rural areas, those with predominantly minority residents, and those with lower area-level income and educational attainment have particularly limited access to healthy food options.[9,10,12-15]

Although disparities in access to healthy food retailers are well-documented, to what extent they influence fruit and vegetable consumption and through what mechanisms remains an area of active research.[15,16] One of the most common methods of operationalizing access to healthy food retailers is to use geospatial analysis to calculate the distance from an individual's residential address to the nearest retailer of healthy foods.[17] However, associations between this measure of access and fruit and vegetable consumption have been mixed.[16] Although documented effect sizes have been small and mostly non-significant, results have been inconsistent with some studies finding that greater distance is associated with lower consumption,[18-20] and others with higher consumption.[19,21,22] One possible explanation for these mixed findings is that Americans do not typically shop at the food store located nearest to their homes,[23] suggesting that focusing on characteristics of the primary food store that consumers actually frequent may be a more appropriate conceptualization of the local food environment and its relationship with dietary behavior.[16] However, few studies have assessed the relationship between distance to the primary food store and have either been conducted among highly

specific populations (e.g., Supplemental Nutrition Assistance Program participants)[24] or geographic areas (e.g., adults in New Orleans, LA).[25]

Even if access to healthy food retailers is an important determinant of fruit and vegetable consumption, the mechanisms through which access influences diet remain largely unexplored. For example, individuals who live closer to healthy food retailers are able to shop for groceries more frequently, which enables them to purchase more produce and rely less on non-perishable, highly processed food items. Although grocery shopping behaviors and home inventories of fresh fruits and vegetables have been strongly associated with greater fruit and vegetable consumption,[25-27] few studies have empirically tested these variables as mediators of the association between access to healthy food retailers and fruit and vegetable consumption. Two prior studies that used these variables as mediators tested them as part of a more complex model within a specific geographic area (i.e., New Orleans, LA and an eight-county region in South Carolina), and found some evidence of that frequency of shopping mediates the relationship between various measures of access to healthy food retailers and fruit and vegetable intake.[28,29]

Additionally, it is possible that the relationship between access to primary food store and fruit and vegetable consumption and the mechanisms through which it operates varies by rurality. Rural areas are less populous, commercially dense, and have fewer retailers of healthy foods, such as supermarkets, as compared to urban areas.[12,15] However, with a few exceptions,[21,22] much of the existing research regarding the role of food environments in influencing dietary behavior has been conducted in urban metropolitan areas that do not have sufficient geographic variability to empirically test rurality as a moderating factor. One study found that among residents of the Brazos Valley in Texas,

greater distance to the nearest supermarket or supercenter was associated with reduced fruit and vegetable intake among rural residents, but not among urban residents.[22] However, no known studies have replicated this finding among a national sample.

The purpose of this study was to assess the relationship between distance to the primary food store and fruit and vegetable consumption and to identify mediators of this relationship among a large national sample of adults in the United States who report shopping at a healthy food retailer as their primary store. Specifically, we sought to answer the following research questions: 1) Is self-reported distance from home to the primary food store associated with fruit and vegetable intake? and 2) To what extent is this relationship mediated by the frequency of shopping for fruits and vegetables and home inventories of fruits and vegetables? Our hypotheses were that greater distance to primary food store would be associated with lower fruit and vegetable consumption, and that this association would be mediated through less frequent shopping and lower home inventories of fruits and vegetables. Additionally, as an exploratory analysis, we also investigated whether these relationships varied by rurality.

Methods

Participants and Procedures

The data for this study came from a self-administered, cross-sectional survey conducted in 2015 by Lightspeed Global Market Insite, Inc. (GMI), an online market research firm. GMI maintains panels of survey respondents who complete self-administered surveys online. All study procedures were approved by the Emory University Institutional Review Board.

GMI emailed panelists who were 18-75 years of age, spoke English, and lived in the US with an invitation to take the survey. All participants provided written informed consent prior to participating in the survey and completed an eligibility screener. Participants who completed the survey were compensated with points they could use towards purchasing gift cards or other incentives through GMI. The sample was matched to the general US population based on age, race/ethnicity, geographic region and annual household income. The 82-item survey instrument was developed by the Emory Prevention Research Center, and contained questions on these domains: characteristics of the home food environment, food acquisition behaviors, perceived community-level access to healthy foods and social capital, dietary behavior, and demographic characteristics.

Of 4.942 respondents, 3,775 (76.4%) were eligible for this analysis. Eligibility criteria included: 1) involvement with grocery shopping for the household (i.e., being the primary food shopper, taking turns with someone else, or going food shopping with someone else), 2) that the primary food store for the household was a retailer of healthy foods (i.e., a large chain grocery store, smaller grocery store, superstore or supercenter, or warehouse club), and 3) complete data on all covariates.

Measures

Fruit and vegetable intake, the outcome variable for this analysis, was measured using the 18-item All-Day Screener developed by the National Cancer Institutes (NCI) as part of the Eating at America's Table study.[33] The screener includes questions about frequency and amount of consumption over the past month for the following fruits and vegetables: 100% fruit juice, fruit, lettuce salad, fried potatoes, other potatoes, dried beans, other vegetables, vegetable soups, and tomato sauce. Frequency response options

ranged from never to 5 or more times per day, and response options for amount consumed were reported in cup equivalents. Responses were used to compute the number of daily servings of fruits and vegetables consumed. The screener and scoring instructions are publicly available on NCI's website.[34] Validation analyses have shown that total fruit and vegetable intake estimated using this screener is positively correlated with estimates from multiple 24-hour dietary recalls (ρ=0.66 for men and 0.51 for women).[33] In keeping with the approach used in prior studies and with guidance obtained from NCI, participants who reported fruit and vegetable intake that exceeded three times the interquartile range, added to the third quartile (11.33 daily servings in this sample) were excluded (n=219).[30-32]

Distance to primary food store, the main predictor variable in this analysis, was measured using a single item created for this study. Participants were asked to report the distance in miles between their home and the store where they most frequently shopped for food.

Frequency of purchasing fresh fruits and vegetables, a mediator in this analysis, was measured using two items, which asked participants how often in the last month the primary food shopper for their home purchased fresh fruit and fresh vegetables, respectively. Similar to previous studies,[26] responses to these items were combined into a single variable representing frequency of shopping for fresh fruits and vegetables, using the most frequent response reported in the original two items.

Home inventories of fruits and vegetables, a mediator in this analysis, measured the variety of fruits and vegetables in the home. Participants were asked whether 15 types of fresh or frozen fruits and 19 types of fresh or frozen vegetables were present in the home over the previous week. Participants could also write in other types of fruits and

vegetables they had in the home, which were categorized and included in the total. Responses were summed to create a total score indicating the number of fruits and vegetables available in the home. This measure was adapted from a previously published version; reported item-specific test-retest reliability for this measure has ranged from 0.63-0.90.[35]

Rurality, a stratification variable in this analysis, was measured using a single item created for this study. Participants were asked, "How would you describe the area where you currently live?" Response options were rural, small town, suburban, or urban. An indicator variable for rurality was used to test for rural-urban differences, with urban and suburban residents categorized together and rural and small town residents categorized together.

Demographic characteristics, which were treated as covariates in this analysis, included age in years, gender, race/ethnicity, marital status, employment status, educational attainment, annual household income, the number of adults and children in the household, and car ownership. We also included an indicator variable for whether or not the participant reported growing edible plants or having a garden in adjusted models as a potential confounder.

Statistical Analyses

After examining the univariate distributions of all study variables, we assessed bivariate relationships between all explanatory variables and the outcome. Rural-urban differences were tested using independent samples t-tests, Wilcoxon-Mann-Whitney tests, and chi-square tests.

Total fruit and vegetable consumption, the outcome for this analysis, was regressed onto distance to primary food store, frequency of shopping for fruits and vegetables, and home inventory of fruits in separate linear regression models. Unstandardized parameter estimates for both bivariate and adjusted models are reported to facilitate direct interpretation of the parameter estimates. Rural-urban differences in these relationships were assessed by adding an interaction term between the predictor variable the indicator variable for rurality. For all analyses, the distribution of the residuals and the variations inflation and tolerance values were examined to ensure the regression assumptions were met and there was no evidence of multicollinearity.

Originally, we intended to use PATH analysis to estimate the effect of frequency of shopping for fruits and vegetables and home inventories of fruits and vegetables as simultaneous mediators. However, our initial models that included both mediators did not have adequate model fit. After respecifying the model to improve fit, the model failed to produce precision estimates (e.g., standard errors and p-values), possibly because of the degree of correlation between frequency of shopping for fruits and vegetables and home inventories of fruits and vegetables (ρ=.41) or recursive relationships between the model variables. We resolved this problem by testing each mediator separately, rather than using PATH analysis.

To assess mediation, we estimated the total, direct, and indirect effects for the total sample in both unadjusted and adjusted analyses using maximum likelihood estimation. The indirect effect was calculated as the product of the direct effects of the explanatory variable on the mediator and the mediator on the outcome,[36] and the significance of this parameter was tested using Sobel's test.[37] The total effect is the sum of the direct and

indirect effect of the explanatory variable on the outcome.[36] Standardized parameter estimates are reported to facilitate comparisons of effect sizes across models. In instances when there was evidence of statistically significant mediation, we computed the proportion of the total effect that was mediated.[36] We used a two-group modelling approach to test for rural-urban differences and tested the difference between the indirect effect estimates for the two groups using a Wald chi-square test of parameter equalities. SAS 9.3 (SAS Institute Inc., Cary, NC) was used for descriptive, bivariate, and regression analyses, and MPlus software (Version 7, Los Angeles, CA: Muthén & Muthén) was used for mediation analyses. Because of the right-skew of the outcome variable, we conducted sensitivity analyses using a log-transformed outcome. Results were not substantively different, and we report the untransformed results in this paper for ease of interpretation.

Results

Participant Demographic and Socioeconomic Characteristics

Respondents were predominantly middle-aged (mean=45.4 years, SD=15.10), female (56.5%), and White (68.0%; Table 1). Approximately 12.5% identified as African American or Black, 14.0% as Hispanic, and 4.9% as Asian. Most were married or living with a partner (56.0%) and either employed for wages or self-employed (55.3%). Almost half had a college degree or higher (49.6%). Annual household incomes ranged widely, with 13.5% earning less than $15,000 annually. Most reported at least one other person in the household (72.0%), and 31.3% reported that at least one child was present in the home. The vast majority of respondents owned a car (91.1%). Most respondents reported living in an urban or suburban area (70.0%; Table 5).

Participant Grocery Shopping Patterns, Home Environment Characteristics, and Fruit and Vegetable Consumption

Most respondents reported that they were involved in grocery shopping for their households (80.6%), and 19.5% reported sharing that responsibility with another person (Table 5). Respondents reported primarily shopping at large chain grocery stores (54.6%), superstores or supercenters (28.9%), smaller grocery stores (11.9%), and warehouse clubs (5.6%). Just under a third reported that they grow edible plants or have a garden (29.8%). Respondents reported a mean distance of 5.7 miles from their residences to their primary food store (SD=8.47). Most (58.6%) reported shopping for fruits and vegetables once per week, and had a mean of 13.7 types of fruits and vegetables in their homes in the previous week (SD=7.32). Respondents reported consuming 2.5 daily servings of fruits and vegetables on average (SD=2.04).

In bivariate analyses, rural and small town residents reported larger mean distance from their homes to the grocery store where they shopped (4.6 miles for urban and suburban residents vs. 8.1 miles for rural and small town residents; $p<.0001$) and slightly lower fruit and vegetable intake (2.5 servings/day for urban and suburban residents vs. 2.4 servings/day for rural and small town residents; $p=.016$). They also reported shopping for fruits and vegetables less frequently (24.0% of urban residents shopped more than once per week vs. 21.2% of rural and small town residents; $p=.004$) and had fewer types of fruits and vegetables in their homes (13.9 for urban and suburban residents vs. 13.3 for rural and small town residents; $p=.014$).

Associations Between Distance to Primary Food Store, Frequency of Shopping for Fruit and Vegetables, and Home Inventories with Fruit and Vegetable Consumption

Greater distance to primary food store was associated with greater consumption of fruits and vegetables in both unadjusted and adjusted analyses (Table 6). In unadjusted models, for every 1-mile increase in distance to the primary food store, respondents reported consuming 0.02 additional servings of fruits and vegetables per day (95% CI: 0.01, 0.03, p<.0001). Adjusting for covariates attenuated the magnitude of the effect. In adjusted analyses, for every 1-mile increase in distance to the primary food store, respondents reported consuming 0.009 additional cup-equivalents of fruits and vegetables per day (95% CI: 0.001, 0.016, p=.03).

More frequent shopping for fruits and vegetables was associated with greater total consumption in both unadjusted and adjusted models. In unadjusted analyses, relative to those who reported shopping less than once per week, mean consumption of fruits and vegetables was 0.84 servings higher among those who shopped once per week (95% CI: 0.67, 1.00, p<.0001) and 2.05-servings higher among those who shopped more than once per week (95% CI: 1.85, 2.24, p<.0001). These associations were attenuated after adjusting for covariates. In adjusted models, relative to those who reported shopping less than once per week, mean consumption of fruits and vegetables was 0.72-servings higher among those who reported shopping once per week (95% CI: 0.56, 0.89, p<.0001) and 1.80-servings higher among those who shopped more than once per week (95% CI: 1.60, 1.99, p<.0001).

Larger home inventories of fruits and vegetables were associated with greater consumption in both unadjusted and adjusted models. In unadjusted models, for each

additional type of fruit or vegetable in the home, respondents reported consuming 0.13 additional servings per day (95% CI: 0.12, 0.14, p<.0001). Results were similar after adjusting for covariates. For each additional type of fruit or vegetable in the home, respondents reported consuming 0.12 additional servings of fruits and vegetables per day (95% CI: 0.11, 0.13, p<.0001).

In adjusted analyses, distance to the primary food store explained very little of the variability in fruit and vegetable intake (R^2<1%). A greater proportion of the variability in fruit and vegetable consumption was explained by frequency of shopping for fruits and vegetables (R^2=10.8%) and home inventories of fruits and vegetables (R^2=20.8%). There was evidence of rural-urban differences in the association between distance to primary food store and fruit and vegetable consumption in unadjusted models (p=.002 for the interaction term). However, after adjusting for underlying differences in the demographic and socioeconomic characteristics of rural/small town and urban/suburban residents, rurality was no longer a statistically significant moderator of this relationship (p=.11 for the interaction term). There was no evidence of significant rural-urban differences in the association between frequency of shopping for fruits and vegetables or home inventories of fruits and vegetables on fruit and vegetable consumption in unadjusted or adjusted analyses.

Mediation Results

Frequency of shopping for fruits and vegetables was not a statistically significant mediator of the effect of distance to primary store on total fruit and vegetable intake in unadjusted (β=0.006, 95% CI: -0.004, 0.02, p=.22) or adjusted analyses (β=-0.006, 95%

CI: -0.004, 0.001 p=.24; Figure 3). Although in unadjusted models, the indirect effect varied by rurality (p=.02 for the difference in the indirect effect in unadjusted models), these differences were largely accounted for by demographic and socioeconomic differences between rural and urban residents (p=.07 for the difference in the indirect effect in adjusted models).

Home inventories of fruits and vegetables was a statistically significant mediator of the relationship between distance to primary store and total fruit and vegetable intake in both unadjusted (β=0.05, 95% CI: 0.04, 0.06, p<.0001) and adjusted analyses (β=0.02, 95% CI: 0.001, 0.03, p=.03; Figure 4). In unadjusted analyses, home inventories of fruits and vegetables accounted for 52.7% of the total effect of distance to primary store on fruit and vegetable consumption. In adjusted analyses, the indirect effect accounted for 83.3% of the total effect. Although the indirect effect through home inventories of fruits and vegetables varied by rurality in unadjusted analyses (p=.0003 for the difference in the indirect effect in unadjusted models), these differences were largely accounted for by demographic and socioeconomic differences between rural and urban residents (p=.08 for the difference in the indirect effect in adjusted models).

Discussion

This analysis sought to test the direction, magnitude, and mechanism through which access to healthy food retailers was associated with fruit and vegetable consumption in a large national sample of adults. Findings indicated that, contrary to expectations, distance to primary food store was positively associated with fruit and vegetable consumption and the magnitude of the effect size was very small. This relationship was mediated by home inventories of fruits and vegetables, but not frequency of shopping for fruits and

vegetables. Rurality was not a statistically significant modifier of these effects after adjust for demographic and socioeconomic characteristics.

Findings from this analysis indicated that greater distance between a participant's home and primary food retailer was associated with increased total fruit and vegetable consumption. Our original hypothesis was that greater distance would be associated with *lower* fruit and vegetable consumption because we conceptualized distance to primary food store as a proxy for access to healthy food retailers within a participant's community. Although unexpected, the direction and magnitude of the total effect of distance to the primary food store is similar to findings from a previous study in New Orleans, LA which found a positive relationship between street-network distance to primary store and fruit and vegetable consumption (OR: 1.06, 95% CI: 1.01-1.12, $p<.05$).[28] Additionally, although the association was statistically significant, the effect size was very small and explained little of the variability in consumption, which raises questions about the public health significance of a change of this magnitude. Because consumption is measured in cup-equivalents, we estimate that the observed effect size represents less than a half-teaspoon increase in total fruit and vegetable consumption per day for each additional mile traveled to the primary food store.

These findings suggest that distance to the primary food store may be not be an adequate proxy for *access* to healthy food retailers, but may instead tap into to other relevant constructs regarding shopping preferences. For example, it is possible that people who eat more fruits and vegetables are more likely to seek out stores with better prices, selection, or quality that may be located farther from their homes, thus explaining this unexpected association. Prior qualitative research has found that proximity is only one of many

factors consumers weigh when making decisions about where to purchase their groceries; other relevant factors may include in-store characteristics, such as prices, selection, and quality of the products sold.[38,39]

Mediation results did not support our original hypothesis that participants whose primary food store was located farther to their homes would eat fewer fruits and vegetables because they shopped for groceries less frequently and purchased less of them when they shopped. These results are inconsistent with previous research, showing that greater objectively measured distance to primary food store was associated with lower fruit and vegetable consumption through less frequent shopping for fruits and vegetables.[28,29] However, differences in the measurement approaches used limit the comparability of results with those from this study. For example, these prior studies measured distance from home to primary food store using geospatial methods, whereas this study used a self-reported measure. Additionally, these studies assessed grocery shopping frequency, whereas this study assessed frequency of shopping for fruits and vegetables. The extent to which these different measurement approaches may influence the results is unknown. Home inventories did appear to be a significant mediator, but in the opposite direction as expected (i.e., that participants whose primary stores are located farther from their homes have higher home inventories and greater intake of fruits and vegetables). Presumably, consumers whose primary food stores are located farther from their homes purchase a greater variety of fresh and frozen fruits and vegetables when they shop for groceries, thus explaining higher home inventories. Although prior studies have documented significant associations between home inventories of fruits and vegetables and total consumption,[26] this analysis is the first to our knowledge to test home inventories of

fruits and vegetables as a mediator of the association between distance to primary food store and fruit and vegetable consumption.

Although we found evidence of significant rural-urban differences in unadjusted analyses, these differences were attenuated after accounting for demographic and socioeconomic differences between these populations. These results suggest that any observed differences between rural and urban residents can be accounted for by underlying demographic and socioeconomic differences between these two groups, and not necessarily by characteristics of their food environments. These findings are surprising, given that rural areas have fewer food outlets as compared to urban areas,[15] with one national study estimating that zip codes located in rural and agricultural areas had 14% of the chain supermarkets that were available in urban zip codes.[12] Our findings differ those from one prior study that assessed variability in the relationship between the food environment and diet by rurality. This study found that of 2,260 adults in the Brazos Valley region of TX, greater objectively-measured distance to the nearest supermarket or supercenter was associated with reduced fruit and vegetable consumption among rural residents, though not among urban residents.[22] However, results from this study cannot be directly compared to this previous one, due to the differences in measuring access (objective vs. self-reoported) and in sampling. Dean et al. assessed distance from residential address to nearest healthy food retailer among a community-based sample, whereas this study assessed self-reported distance from residential address to primary food store among shoppers at healthy food retailers.

Strengths of this analysis include that it uses data from a large, national sample with sufficient geographic variability to stratify by rurality. Additionally, the outcome

measures included questions about both frequency and amount consumed, which is a methodologically stronger approach than alternative measures that ask about frequency of consumption alone.

Limitations of this analysis include that it relies on cross-sectional data, limiting our ability to test causal relationships. Additionally, though the dataset included a large national sample balanced to the US population on key demographic characteristics, this analysis reports results from a subset of respondents, and the extent to which these results are representative of shoppers at healthy food retailers in the United States is unknown. Additionally, the method of constructing the sample may have introduced bias. For example, although less than 5% of respondents were excluded because they do not use a traditional retailer of healthy foods as their primary food store, by systematically excluding these respondents, we may have also systematically excluded people with lower access to healthy foods within their communities and/or rural residents. This limits the comparability of this study with other similar studies that assessed objectively measured access to healthy food retailers among a community-based sample. Regarding the measures used in this study, we were unable to measure objective access to healthy food retailers within participants' communities, and instead conceptualized proximity to primary food retailer as a proxy for access. However, results from this study raise questions about the extent to which this measure is a good proxy for access, as it may be tapping into preferences or other factors adults use when deciding where to shop for food. Additionally, several of the measures asked participants about different sources of fruits and vegetables in their diets. For example, the outcome measure asked about consumption of fresh, frozen, and canned fruits and vegetables. By contrast, the mediator

about shopping frequency asked about purchasing fresh fruits and vegetables, and the mediator of home inventories asked about the availability of fresh and frozen fruits and vegetables in the home. This measure created for this study by the investigators and its psychometric properties are unknown.

Despite these limitations, these results add to the growing area of research investigating food acquisition practices as a potential mechanism through which consumers navigate their food environments. Recommendations for future research include using an objective measure of access to healthy food retailers, using a community-based sample, and assessing other potential food acquisition behaviors, such as store type of quantity of fruits and vegetables in the home, as mediators. These results combined with those of the present study will add to the growing body of literature assessing the mechanisms through which food retailer environments may influence dietary behavior.

Figures and Tables

Table 5. Characteristics of National Home Environment Survey Respondents, Stratified by Rurality (N=3,775)

	Total N=3,775 mean ± SD or n (%)		Urban and Suburban Residents n=2,642 mean ± SD or n (%)		Rural and Small Town Residents n=1,133 mean ± SD or n (%)		*p*
Age (years)	45.4	± 15.10	45.2	± 15.16	46.1	± 14.94	.08
Female	2,136	(56.6)	1,476	(55.9)	660	(58.3)	.18
Race							<.0001
White	2,567	(68.0)	1,681	(63.6)	886	(78.2)	
African American or Black	473	(12.5)	392	(14.8)	81	(7.2)	
Hispanic	527	(14.0)	407	(15.4)	120	(10.6)	
Asian	184	(4.9)	147	(5.6)	37	(3.3)	
Other	24	(0.6)	15	(0.6)	9	(0.8)	
Marital Status							.003
Married or living with partner	2,113	(56.0)	1,447	(54.8)	666	(58.8)	
Divorced, separated, or widowed	597	(15.8)	407	(15.4)	190	(16.8)	
Single	1,065	(28.2)	788	(29.8)	277	(24.5)	
Employment Status							<.0001
Employed for wages or self-employed	2,088	(55.3)	1,527	(57.8)	561	(49.5)	
Retired, a homemaker, or a student	1,356	(35.9)	893	(33.8)	463	(40.9)	
Unemployed	331	(8.8)	222	(8.4)	109	(9.6)	
Education							<.0001
Some high school or less	91	(2.4)	53	(2.0)	38	(3.4)	
High school or GED	618	(16.4)	360	(13.6)	258	(22.8)	
Some college/technical school	1,194	(31.6)	800	(30.3)	394	(34.8)	
College graduate or higher	1,872	(49.6)	1,429	(54.1)	443	(39.1)	
Household Income							<.0001
Less than $15,000	510	(13.5)	329	(12.5)	181	(16.0)	

	Total N=3,775		Urban and Suburban Residents n=2,642		Rural and Small Town Residents n=1,133		*p*
	mean ± SD or n (%)		mean ± SD or n (%)		mean ± SD or n (%)		
$15,000 - $49,999	1,418	(37.6)	942	(35.7)	476	(42.0)	
$50,000 or more	1,847	(48.9)	1,371	(51.9)	476	(42.0)	
Household size							.002
1	1,056	(28.0)	760	(28.8)	296	(26.1)	
2	1,126	(29.8)	764	(28.9)	362	(32.0)	
3	684	(18.1)	491	(18.6)	193	(17.0)	
4	569	(15.1)	415	(15.7)	154	(13.6)	
5+	340	(9.0)	212	(8.0)	128	(11.3)	
Children Present in the Household	1,180	(31.3)	823	(31.2)	357	(31.5)	.83
Owns at Least One Car	3,438	(91.1)	2,384	(90.2)	1,054	(93.0)	.006
Grocery Shopping Involvement							.24
I am the only primary food shopper	3,041	(80.6)	2,146	(81.2)	895	(79.0)	
I take turns with someone else	400	(10.6)	274	(10.4)	126	(11.1)	
I go with someone else	334	(8.9)	222	(8.4)	112	(9.9)	
Primary Food Store Type							<.0001
Large chain grocery store	2,062	(54.6)	1,523	(57.7)	539	(47.6)	
Smaller grocery store	450	(11.9)	269	(10.2)	181	(16.0)	
Superstore or supercenter (e.g., Wal-Mart or Target)	1,090	(28.9)	706	(26.7)	384	(33.9)	
Warehouse Club (e.g., Sam's Club or Costco)	173	(5.6)	144	(5.5)	29	(2.6)	
Grows Edible Plants or Gardens	1,124	(29.8)	714	(27.0)	410	(36.2)	<.0001
Self-Reported Distance from Home to Primary Food Store (mi)	5.7	± 8.47	4.6	± 7.70	8.1	± 9.61	<.0001
Frequency of Shopping for Fruits and Vegetables							.004
Less than once per week	686	(18.2)	446	(16.9)	240	(21.2)	

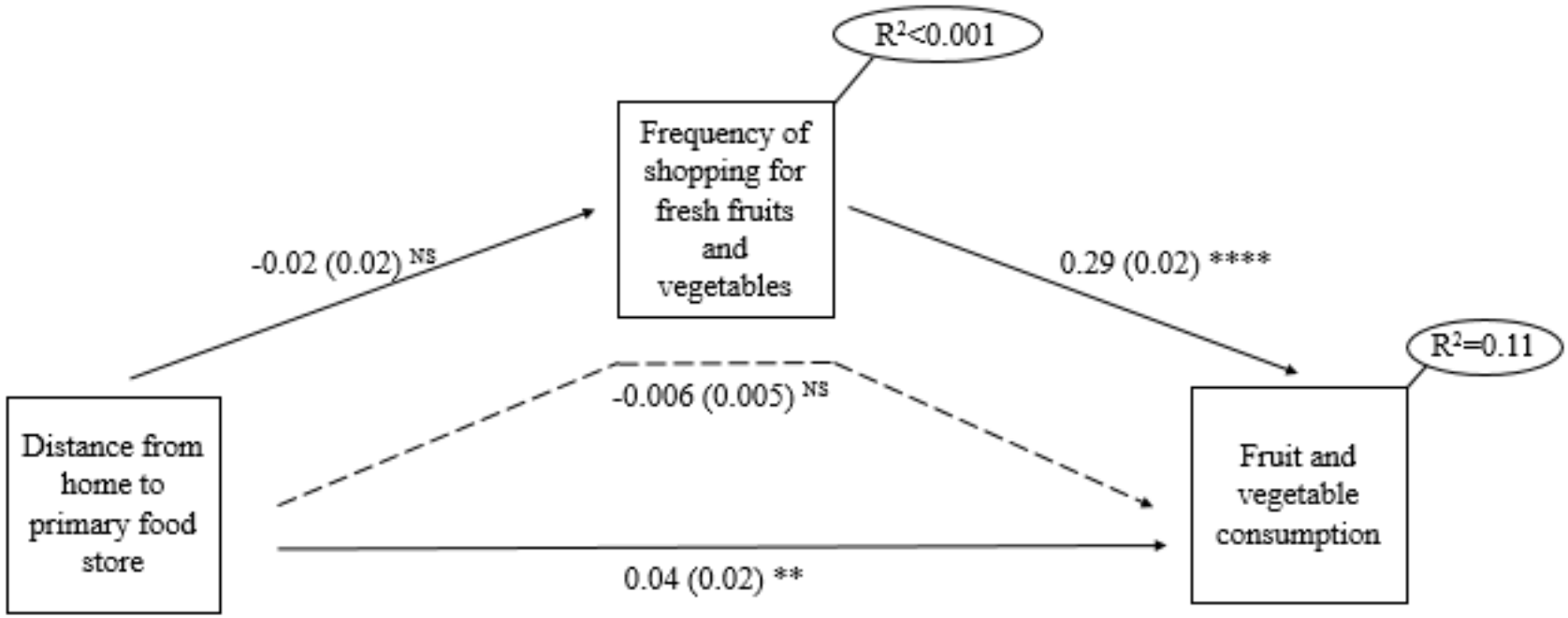
	Total N=3,775 mean ± SD or n (%)		Urban and Suburban Residents n=2,642 mean ± SD or n (%)		Rural and Small Town Residents n=1,133 mean ± SD or n (%)		*p*
Once per week	2,215	(58.7)	1,561	(59.1)	654	(57.7)	
More than once per week	874	(23.2)	635	(24.0)	239	(21.1)	
Home Inventory of Fruits and Vegetables	13.7	± 7.32	13.9	± 7.47	13.3	± 6.93	.014
Fruit and Vegetable Intake (Daily Servings)	2.5	± 2.04	2.5	± 2.07	2.4	± 1.97	.016

Table 6. Community and Home Food Environment Predictors of Fruit and Vegetable Consumption among National Home Environment Survey Respondents and Evidence of Rural-Urban Variability (N=3,775)

Variable	Unadjusted Estimates			Rural-Urban Difference	Adjusted Estimates			Rural-Urban Difference
	β	(95% CI)	*p*	*p*	β	(95% CI)	*p*	*p*
Distance to Primary Food Store (mi)	0.02	(0.02, 0.03)	<.0001	.0007	0.009	(0.001, 0.02)	.03	.11
Frequency of Shopping for Fruits and Vegetables								
Less than once per week	ref				ref			
Once per week	0.83	(0.67, 1.0)	<.0001	.13	0.72	(0.56, 0.89)	<.0001	.09
More than once per week	2.0	(1.9, 2.2)	<.0001	.63	1.80	(1.60, 1.99)	<.0001	.64
Home Inventory of Fruits and Vegetables	0.13	(0.12, 0.14)	<.0001	.17	0.12	(0.11, 0.13)	<.0001	.60

Note. Each predictor was tested in a separate linear regression model, using total fruit and vegetable intake (number of daily servings) as the outcome. All parameter estimates are unstandardized. Rural-urban differences were tested using an interaction term between the predictor and an indicator variable for rurality. Adjusted models include the following covariates: age, sex, race, marital status, education, income, household size, the presence of children in the home, car ownership, role in grocery shopping, primary store type, and home gardening.

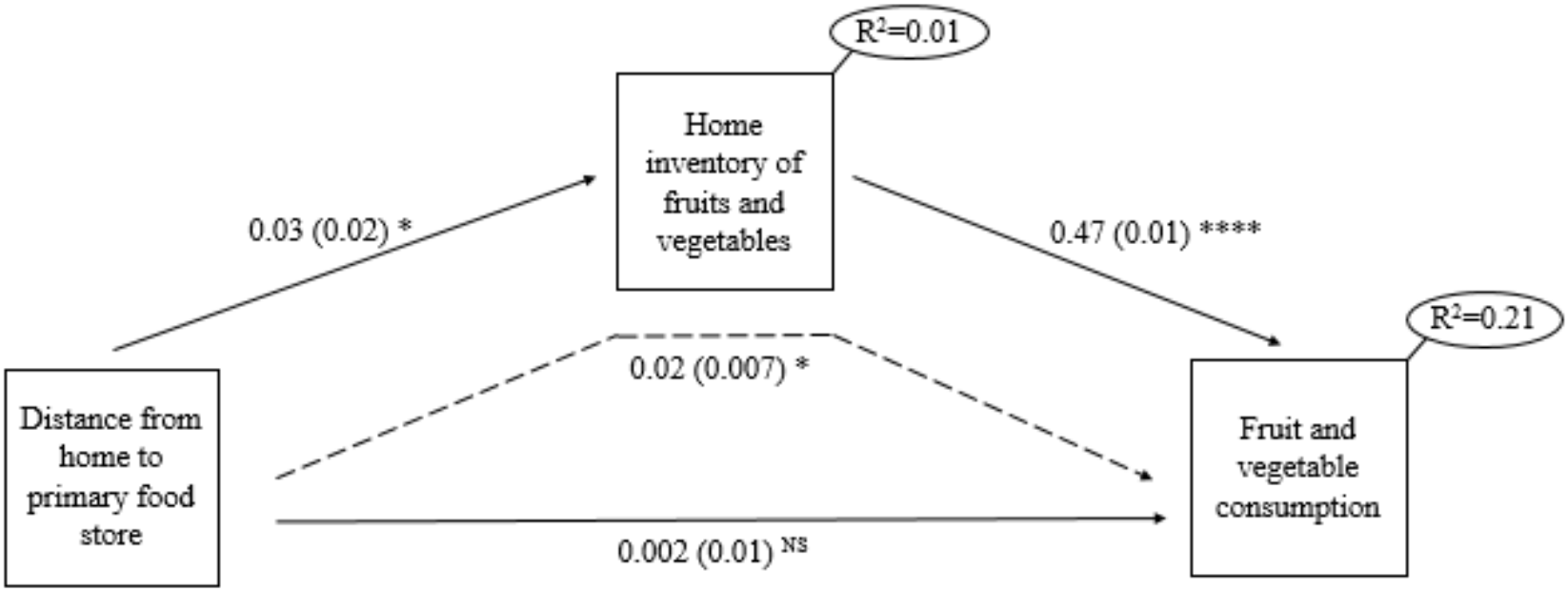
Figure 3. Frequency of Shopping for Fruits and Vegetables as Mediator of the Association between Distance to Primary Food Store and Fruit and Vegetable Consumption Among National Home Environment Survey Respondents (N=3,775)



*p<.05, **p<.01, ***p<.001, ****p<.0001

Note. Solid lines indicate direct effects and dashed line indicates the indirect effect. Parameter estimates are presented with standard errors in parentheses. All parameter estimates are standardized and adjusted for the following covariates: age, sex, race, marital status, education, income, household size, the presence of children in the home, car ownership, role in grocery shopping, primary store type, and gardening.

Figure 4. Home Inventories of Fruit and Vegetables as a Mediator of the Association between Distance to Primary Food Store and Fruit and Vegetable Consumption Among National Home Environment Survey Respondents (N=3,775)



*p<.05, **p<.01, ***p<.001, ****p<.0001

Note. Solid lines indicate direct effects and dashed line indicates the indirect effect. Parameter estimates are presented with standard errors in parentheses. All parameter estimates are standardized and adjusted for the following covariates: age, sex, race, marital status, education, income, household size, the presence of children in the home, car ownership, role in grocery shopping, primary store type, and gardening.

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CHAPTER 4. Does the Food Retail Environment Modify the Efficacy of a Behavioral Intervention to Improve Dietary Quality?

Abstract

Introduction: The typical American diet does not adhere to federal nutrition guidelines, and few low-cost behavioral interventions to improve diet quality exist. Even if such interventions can be identified, they may not be uniformly effective for all participants. The aims of this study were to assess the efficacy of a home environment-focused coaching intervention for improving dietary quality and to explore three measures of access to healthy food retailers as potential moderators of the intervention efficacy.

Methods: The intervention was evaluated using a two-group randomized design with 6 and 12-months follow-up. Dietary quality was measured using multiple 24-hr recalls and scored using the Healthy Eating Index-2010 (HEI-2010). Tested moderators included proximity to the nearest healthy food retailer and the availability and density of healthy food retailers within a 1-mile radial buffer of participants' residential addresses.

Results: Trial participants were 349 middle-aged overweight or obese women living in the Georgia. Intervention participants reported small but significant improvements in dietary quality at six-months follow-up relative to control participants (+3.41 ± 13.43 intervention vs. +2.02 ± 12.26 control, p=.008; Cohen's D=0.16). Subcomponent analysis indicated that intervention participants reported greater vegetable consumption and reduced intake of solid fats, alcoholic beverages, and added sugars. No statistically significant intervention effect was evident at twelve-months follow-up. Although moderation results were not statistically significant, they suggested that the intervention may have attenuated the effect of limited access to healthy food retailers on dietary

quality, with the proximity measure access showing the strongest effect. The effect of a 1-mile increase to the nearest healthy food retailer on HEI-2010 total score was greater among control participants (β=-0.18, 95% CI: -0.42, 0.07) relative to intervention group participants (β=0.01, 95% CI: -0.24, 0.25).

Discussion: Consistent with the intervention's theory of change, the intervention resulted in small but significant short-term improvements in dietary quality. Though we found no evidence of statistically significant moderation, results suggest that exposure to the HHHF intervention may have attenuated the effect of access to healthy food retailers on dietary quality. More research is needed regarding the potential moderating effect of local food environments on intervention efficacy.

Introduction

The quality of the typical American diet does not adhere to federal nutrition guidelines, which may partly explain the high prevalence of obesity and chronic disease in this country.[1] The federal government defines a healthy diet as rich in fruits and vegetables, whole grains, low-fat dairy products, and lean proteins, and limited in saturated and trans fats, sodium, and added sugars.[2] However, the majority of Americans do not meet the federal government's minimum recommended intake of fruits, vegetables, and whole grains.[3] Instead, energy intake disproportionately comes from energy-dense food sources, including solid fats, added sugars, and alcoholic beverages.[3] According to recent meta-analyses, populations consuming diets that better adhere to federal nutrition guidelines have lower rates of all-cause mortality and incident cardiovascular disease, cancer, and diabetes mellitus.[4,5] Low-cost behavioral interventions to improve dietary quality are needed.

The home food environment may be an appropriate target for interventions to improve dietary quality. Characteristics of the home food environment, including the availability of healthy and unhealthy foods, the use of non-home food sources, grocery shopping practices, and food preparation method, are associated with a range of dietary behaviors among adults and children,[6-8] including dietary quality.[9,10] Several interventions to improve the home food environment have resulted in increased fruit and vegetable consumption,[11] decreased total energy intake,[12] and improved weight-related outcomes.[12-14] However, no known evaluations have assessed the impact of these interventions on overall dietary quality.

Even if interventions to improve dietary quality can be developed and implemented, they may not be uniformly effective for all participants. Many behavioral interventions to modify dietary behavior involve participants changing how they relate to their food environments by altering their food purchasing patterns.[11-14] Neighborhoods with greater access to healthy food retailers may help facilitate participants in making health-promoting changes to their food shopping behaviors and diets, while neighborhoods with limited healthy food retailers may hinder them.

Several prior studies have documented that characteristics of the broader neighborhood food retail environment may moderate the efficacy of interventions to improve dietary behavior and weight-related outcomes.[15-19] Results have been mixed; some studies have found evidence of statistically significant moderation,[15,17,19] although others have not.[18] However, these results are difficult to compare, as they have focused on different interventions, populations, outcome measures, and definitions of the food retail environment. Consistent with the observational literature,[20] the most commonly used

measures of access to healthy food retailers have been proximity to the nearest retailer[15,17,19] or the presence or density of supermarkets within geographic areas ranging from 0.5-3 miles around the participants' residence.[15,18,19] Other less commonly used measures included perceptions of the local food environment and the modified retail food environment index.[19]

The purpose of this study was to conduct a secondary analysis of data from the Healthy Homes/Healthy Families (HHHF) randomized trial to assess whether a home environment-focused coaching intervention to prevent weight gain resulted in improved dietary quality among low-income overweight and obese women. Additionally, we sought to investigate the extent to which neighborhood-level access to healthy foods modified the efficacy of the intervention at improving dietary quality. We hypothesized that participants randomized to the intervention would show greater improvements in dietary quality relative to those randomized to the control condition and that the intervention effect would be stronger among participants living in areas with greater access to healthy food retailers.

Methods

This study is a secondary analysis of data from a randomized trial that evaluated the Healthy Homes / Healthy Families intervention.[12] Trial participants were referred to the study between February 2011 and December 2012 by providers at nine community health center clinical sites in the southwestern region of Georgia. Eligible participants were overweight and obese women aged 35-65 years who were not pregnant and who lived with at least one other person no farther than 30 miles from the referring clinic. Trained interviewers collected data by telephone at baseline, six, and twelve-months follow-up. Of the 948 women referred to the study, 751 were screened for eligibility, and

349 completed baseline data collection and were randomized to condition. The majority of participants (n=288, 82.5%) completed data collection at six-months follow-up, and 268 participants (76.8%) at twelve-months follow-up. All study procedures were approved by the Emory University Institutional Review Board.

Intervention Description

Condition (intervention vs. control) was the main exposure variable for this analysis. Participants randomized to the intervention group received the HHHF intervention, and those randomized to the control condition received three mailings of nutrition and physical activity educational materials developed by the federal government. A detailed description of the intervention has been published previously.[12] Briefly, HHHF is an intervention to prevent weight gain by making the home nutrition and physical activity environments more supportive of healthy eating.

The intervention consisted of seven contacts (three in-person and four by telephone) with a health coach over sixteen weeks. All participants received a home environment profile indicating healthy and less healthy aspects of the home environment that was tailored on results from the baseline survey responses. Health coaches used the home environment profile to guide each participant to select a total of six healthy actions to make the home environment more supportive of healthy eating and physical activity (e.g., always having a low-calorie beverage at home instead of sugar soda and/or sweet tea or keeping one piece of exercise equipment in a visible location and committing to using it once a week). Each healthy action was recorded in a family contract, which was signed by the participant and the coach. Participants were mailed materials to support these healthy actions (e.g., a portion plate or a water bottle). Process evaluation results

indicated that most participants (74.4%) randomized to the intervention condition received the entire intervention.[12]

Measures

Dietary Quality

Dietary quality, operationalized as the Healthy Eating Index-2010 (HEI-2010) at six and twelve-month follow-up, was the outcome variable for this analysis. Self-reported dietary intake data was collected by interviewer-administered 24-hour dietary recalls on one weekday and one weekend day on unannounced, nonconsecutive days using the Nutritional Data System for Research (NDSR, version 2010, Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). Prior to the interviews, participants received a printed food amount booklet to aid them in estimating portion sizes. The 24-hour dietary recall is the gold standard measure of self-reported dietary intake, and is more highly correlated with serum carotenoid levels (r=.42) as compared to brief fruit and vegetable consumption measures.[21]

We used the 24-hour dietary recall data to calculate the HEI-2010, which is a measure of adherence to Dietary Guidelines for Americans 2010, the federal government's nutrition guidelines at the time of the study.[22,23] The HEI-2010 total score ranges from 0-100 and is comprised of twelve subcomponents: consumption of total fruit; whole fruit; total vegetables; dark-green and orange vegetables and legumes; total grains; whole grains; milk; meat and beans; oils; saturated fats; sodium; and solid fats, alcoholic beverages, and added sugars (SoFASS). Higher total and subcomponent scores indicate better dietary quality. As described in more detail in a previous publication, the HEI-2010 score was calculated for each recall day, and the scores from the two days were averaged.[9]

Prior research has shown that higher HEI scores are correlated with a range of plasma biomarkers indicative of better dietary quality,[24] that the HEI-2010 can distinguish between populations known to have differences in dietary quality,[25] and it is a reliable method of measuring dietary quality (Cronbach's alpha=.68).[25]

Access to Healthy Food Retailers

The moderator for this analysis was access to healthy food retailers, which was operationalized in three ways: proximity, availability, and density of healthy food retailers relative to the participant's residential address.

Participants provided their residential addresses at baseline, which were geocoded in ArcMap 10.5.1 (Environmental Systems Research Institute [ESRI]. ArcGIS Desktop: Release 10. Redlands, CA) using an address locator from 2012 obtained from ESRI. Of the 349 participants, 264 addresses (76%) were matched; 5 (1%) were tied, meaning there was more than one candidate for the best match; and 80 (23%) were unmatched. Unmatched addresses were resolved by searching for their location using Google Maps, an open-source mapping software, and importing the latitude and longitude coordinates. Of the 80 unmatched addresses, 25 could not be rematched and were excluded from the moderation analysis.

The locations of all food retailers open for business in the study area in 2012 was obtained from a commercial mailing list from ReferenceUSA. Addresses were geocoded using the same procedure that was used to geocode residential addresses. In total, 2,825 stores (88%) were matched, 30 (1%) were tied, and 340 (11%) were unmatched. Of the unmatched addresses, 274 were located in Google Maps. Of the total stores geocoded, 114 were defined as healthy food retailers, which were identified by their primary North

American Industry Classification System (NAICS) code and name recognition. Healthy food retailers included supermarkets (NAICS: 44511001-5 with 50+ employees, n=74), supercenters (NAICS: 452111, n=35), and warehouse clubs (NAICS: 425910 & 45291001, n=5).

All moderator variables were created in ArcGIS. For the proximity measure, the spatial join function was used to calculate the Euclidean (straight-line) distance in miles from the participant's home to the nearest healthy food retailer. Proximity was treated as a continuous variable in all analyses. For the availability measure, we constructed 1-mile buffers around each participants' home and created a dichotomous indicator variable for the presence of at least one healthy food retailer within the buffer (coded as 0/1). For the density measure, a spatial join was used to calculate the number of healthy food retailers within the 1-mile buffer. We trichotomized the responses for this variable into three levels (0, 1, and 2+) due to concerns about sparse data, as only two participants had greater than two healthy food retailers within the buffer. We selected these geographic buffers to facilitate comparisons with similar studies that have been previously published.[15,19]

Covariates

Both individual- and neighborhood- level variables were included as potential covariates. At baseline, participants reported their age, race, marital status, employment status, educational attainment, annual household income, the number of adults, and the presence of children living in the home. Self-reported height and weight was used to calculate body mass index (kg/m^2) at baseline.

Neighborhood-level variables included an indicator variable for urban vs. rural and two measures of area-level socioeconomic status. We used the US Census' method of characterizing participants as living in a rural vs. urban area. Participant addresses that fell within a 2010 US Census-designated urbanized area, defined as an area with 50,000 or more people, were coded as urban; all others were coded rural. Participants' census tract of residence was determined in ArcGIS and matched to census data to determine the percent of residents living in poverty and the median household income.

Statistical Analysis

The univariate distribution of the main outcome variable was assessed for normality, missingness, and geospatial clustering. Participants who were lost to follow-up were older ($p=.003$) and more likely to have been randomized to the intervention condition ($p=.03$). There was negligible evidence of geospatial clustering of the outcome at the census tract-level (intraclass correlation coefficient=6.83% for the HEI-2010 total score at baseline). Bivariate associations between all study variables were also assessed. Variables that were theoretical confounders and those that were associated with the main exposure, outcome, moderator, or with an indicator variable for those who were unable to be geocoded at $p<.10$ were treated as covariates in adjusted models. Two participants had missing data on covariates and were excluded from adjusted analyses.

The main effect of the intervention on six and twelve-month change in HEI-2010 total and subcomponent scores were estimated using linear regression. For these models, we regressed the HEI-2010 total and subcomponent scores at follow-up onto the baseline values and the main exposure variable of group (intervention vs. control). This is the preferred method of analyzing continuous outcome data from a randomized trial in

instances when there are differences in the outcome at baseline despite randomization and the baseline and follow-up scores and not strongly correlated.[26] The coefficient of the group variable represents the main intervention effect (i.e., the mean difference in the outcome comparing the intervention and control groups). The standardized effect size of the intervention was estimated using Cohen's D.[27] Unadjusted results are reported, though we also conducted a sensitivity analysis for the main intervention effect adjusting for covariates, and the statistical significance remained the same. For all analyses, the distribution of the residuals and the variance inflation and tolerance values were examined to ensure the regression assumptions were met.

Moderation analyses were conducted among the 324 participants whose residential addresses could be geocoded. To assess moderation, the variable for access to healthy food retailers and an interaction term between that variable and group were added to the models as predictors. Several sensitivity analyses were conducted for each moderator. For the availability and density measures, results for the 1-mile buffer were compared with a 5- and 10-mile buffer. For all moderation analyses, we centered the HEI-2010 total score by subtracting it from the mean score among all participants to improve the interpretability of the intercept. Results were adjusted for the following covariates: participant age, marital status, employment status, educational attainment, annual household income, the number of adults in the household, the number of children in the household, an indicator variable for urban vs. rural, percent poverty within the census tract, and median household income within the census tract. Additionally, for the availability and density-based measures of access to a healthy food retailer, we attempted to control for the total number of food retailers within the geographic area, but were

unable to include this as a covariate due to variance inflation resulting from multicollinearity. All analyses were conducted in SAS version 9.3 (SAS Institute Inc., Cary, NC).

Results

Characteristics of Trial Participants

The majority of HHHF trial participants were middle-aged (mean age=50.2 years, SD=8.1) African American (84.5%) women who were overweight or obese at baseline (mean BMI=28.2, SD=8.5; Table 1. Approximately 36.4% reported that they had a high school degree or equivalent, and 11.6% reported that they had graduated from college. Many reported full- (34.1%) or part-time employment (10.0%). Almost one-third of participants reported an annual household income of less than $10,000 per year, and nearly half reported that they were either married or living with a partner (46.1%). There were no statistically significant differences in demographic variables between the intervention and control groups.

Of the 324 participants whose addresses could be geocoded, most (n=208, 64.2%) lived in an urban area (Table 1). Participants' census tracts of residence had a mean poverty rate of 32.4%, and the median household income was $32,040 on average. Participants' residential addresses were located an average of 6.56 miles from the nearest healthy food retailer. Approximately 24.4% of participants had at least one healthy food retailer within 1 mile of their home, with 15.4% having one healthy food retailer and 8.9% having two or more healthy food retailers within 1 mile. The only statistically significant difference between groups was that participants randomized to the control group were more likely to have at least one healthy food retailer within 1 mile of their home (p=.03).

At baseline, intervention participants had slightly higher HEI-2010 scores (51.09 ± 11.61 for intervention vs. 49.50 ± 11.09 for control), though this difference was not statistically significant (p=.19; Table 3). Subcomponent analysis indicated that intervention and control participants differed on consumption of total vegetables (2.58 ± 1.38 for intervention vs. 2.28 ± 1.33 for control, p=.04), dark-green and orange vegetables and legumes (2.08 ± 1.80 for intervention, 1.61 ± 1.65 for control, p=.01), and saturated fat (6.40 ± 2.67 for intervention, 5.62 ± 2.93 for control p=.01).

Intervention Impact on Dietary Quality

At six-months follow-up, intervention participants showed greater improvements in dietary quality relative to control participants (+3.41 ± 13.43 for intervention group vs. +2.02 ± 12.26 for control group, p=.008). Subcomponent analysis indicated that intervention participants reported greater consumption of total vegetables (+0.37 ± 1.88 among intervention group vs. +0.26 ± 1.91 among control group, p=.008) and reduced consumption of solid fats, alcoholic beverages, and added sugar (+1.70 ± 4.99 among intervention group vs. +0.90 ± 5.24 among control group, p=.02). No statistically significant intervention effect was evident at twelve-months follow-up. The standardized effect size was 0.16 at six months and 0.13 at twelve-months follow-up.

Moderation by Access to Healthy Food Retailers

Proximity to a Healthy Food Retailer

Results for the moderating effect of distance to the nearest healthy food retailer from the participant's residence are shown in Table 3 and Figure 1. Although all results were statistically non-significant, the direction and magnitude of the effect sizes suggested that distance to the nearest healthy food retailer had an inverse effect on HEI-

2010 scores at six-months follow-up among control group participants, but was attenuated among intervention group participants. Among the control group, for each 1-mile increase in distance to the nearest healthy food retailer, mean HEI-2010 scores were 0.18-units lower at follow-up, though this association was not statistically significant (95% CI: -0.42, 0.07, p=.16). Among the intervention group, for each 1-mile increase in distance to the nearest healthy food retailer, HEI-2010 scores increased by 0.01-units, although this association was also not statistically significant (95% CI: -0.24, 0.25, p=.96). The interaction term, testing the difference in the association between proximity to a healthy food retailer and HEI-2010 scores at follow-up conditional on group assignment was not statistically significant (β=0.18, 95% CI: -0.13, 0.50, p=.25).

Availability of a Healthy Food Retailer

Results for the moderating effect of the presence of a healthy food retailer within one mile of the participant's residence are shown in Table 3. Although all results were statistically non-significant, the direction and magnitude of the effect sizes suggest that the presence of a healthy food retailer within one mile had a positive effect on HEI-2010 scores among both groups, and was stronger for control group participants. Control group participants with a healthy food retailer within 1 mile scored 3.61-units higher on HEI-2010 at follow-up as compared to those who did not, though this relationship was not statistically significant (95% CI: -0.76, 7.99, p=.11). Intervention group participants with a healthy food retailer within 1 mile scored 2.64-units higher on the HEI-2010 at follow-up as compared to those who did not, though this relationship was also not statistically significant (95% CI: -2.36, 7.64, p=.30). The interaction term, testing the difference in the association between the availability of a healthy food retailer and HEI-2010 scores at

follow-up conditional on group assignment, was not statistically significant (β=-0.97, 95% CI: -7.39, 5.44, p=.77).

Density of Healthy Food Retailers

Results for the moderating effect of density of healthy food retailers within a 1-mile buffer of the participant's residence are shown in Table 3 and Figure 2. Although all results were statistically non-significant, the direction and magnitude of the effect sizes suggest that the presence of a healthy food retailers within one mile had a positive effect on HEI-2010 scores among both groups, and was stronger for control group participants. In unadjusted and adjusted analyses, there was a positive relationship between the number of healthy food retailers and HEI-2010 scores at 6-months follow-up among intervention and control groups, but the effect of the food retailer environment on dietary quality was stronger for control group participants. For each additional healthy food retailer within 1 mile, HEI-2010 scores increased by 2.74-units among the control group, and this association was statistically significant (95% CI: 0.69, 4.79, p=.009). For each additional healthy food retailer within 1 mile, HEI-2010 scores increased by 2.63-units among the intervention group, though this association was not statistically significant (95% CI: -0.73, 5.98, p=.12). The interaction term, testing the difference in the association between density of healthy food retailers within 1 mile and HEI-2010 scores at follow up conditional on group assignment was not statistically significant (β=-.11, 95% CI: -3.98, 3.71, p=.95).

Discussion

Results suggest that a moderate-intensity coaching intervention focused on making health-promoting changes to the home environment resulted in short-term improvements in the quality of overweight and obese women's diets to make them better aligned with

federal nutrition guidelines. Changes in diet appeared to be driven by improvements in consumption of total vegetables and solid fats, alcoholic beverages, and added sugars. These findings are consistent with results from a previously published process evaluation of the intervention, which documented that the healthy actions most commonly selected by intervention participants included always having a low-calorie beverage available instead of sugar soda and/or sweet tea (51.2%), identifying one unhealthy food or drink and not allowing it in the home (53.6%), and purchasing fresh vegetables and fruits at least once a week and making them easy to see and grab (43.6%).[12]

Although the intervention effect on dietary quality was statistically significant, the standardized effect size was small (i.e.,<0.20).[27] The clinical significance of a change in HEI-2010 scores of this magnitude is yet unknown. To date, most studies that have used the HEI-2010 have been cross-sectional and descriptive; few longitudinal studies or experimental studies have been published. Intervention participants reported a mean improvement of +3.41 units in the HEI-2010 total score from baseline to six-months follow-up, which is consistent with the magnitude observed in previous intervention studies (range: +2.6-6.1-unit increases).[28-31] However, none of these interventions was comparable to HHHF. For example, tested interventions included an evaluation of the USDA-funded nutrition education intervention for low-income people,[28] financial incentives to increase fruit and vegetable purchase among SNAP recipients,[30] a health education intervention to reduce sugar-sweetened beverage consumption among adults,[29] and a church-based diet and physical activity intervention among African Americans.[31]

Although not explicitly tested as part of this analysis, these results help interpret previous findings from this trial and clarify the intervention's mechanisms of change. As

reported previously, HHHF participants reported significant and sustained reductions in total energy intake. At 6-months follow-up, HHHF intervention participants reported greater reductions in total energy intake relative to control participants (-274 ± 583 kcal/d among intervention group vs. -69 ± 594 kcal/d among control group, p=.003).[12] Given that previous research has shown that the HEI-2010 measures dietary quality independent of energy intake,[25] these results suggest that HHHF participants may have decreased their total caloric intake in part by improving the diets such that they better aligned with federal nutrition guidance. Furthermore, these modifications were enough to result in differential self-reported weight loss between the two groups (-9.1 ± 16.5 lbs among intervention group vs. -5.0 ± 13.7 lbs among control group, p=.03).[12]

This study also found evidence suggesting that the HHHF may have attenuated the effect of poor access to healthy foods on dietary quality. This finding differed from our original hypothesis that the effect of the HHHF intervention on dietary quality would be stronger among participants who lived in communities with greater access to healthy food retailers because these environments would support participants in making health-promoting changes to their home food environment and diet. Our results did not support this hypothesis, but suggested a new direction for future research instead. We found evidence that control group participants with poorer access to healthy food retailers (defined by either proximity, presence, or density) had poorer dietary quality, but that this relationship was attenuated by participation in the HHHF intervention. Many of the healthy actions selected by participants involved changing food purchasing patterns. Though not formally tested by this study, it is possible that the HHHF intervention

motivated participants to change their food purchasing patterns, regardless of the characteristics of their community food environments.

To our knowledge, only two previous studies have examined access to healthy food retailers as a potential moderator of interventions to improve dietary quality. One study used data from a lifestyle intervention to reduce cardiovascular disease risk among 249 adults in North Carolina.[19] This analysis found that 6-month change in dietary quality, measured by the Dietary Risk Assessment, was not correlated with street network distance to the nearest supermarket in miles (ρ=0.07, p=.38) or the density of supermarkets within a 1-mile buffer of the participant's home (ρ=-0.10, p=.17). A different study used data from a health education intervention to improve dietary fiber intake among 204 obese adults with metabolic syndrome in Massachusetts.[15] This analysis found that increased distance from the participant's residence to the nearest healthy food retailer attenuated 6-month improvements in dietary quality, measured using the Alternate Healthy Eating Index, among the intervention group, though this relationship was not statistically significant (β=-0.37, 95% CI: -1.07, .33). This study also examined the density of healthy food retailers within a 1-mile buffer, but found no evidence of statistically significant moderation, and did not present parameter estimates in the paper.

Given that none of the interventions tested in this literature, including HHHF, were explicitly designed to improve dietary quality and that all studies were likely not powered to conduct these secondary analyses, it is not surprising that most results were not statistically significant. Still, these results are suggestive of a potential moderating

influence of the community food retailer environment on intervention efficacy and warrant further exploration in future studies.

Strengths of this study include the two-group randomized design and the use of multiple 24-hour dietary recalls to measure dietary intake. Limitations of this analysis include that this trial was not powered to detect changes in the HEI-2010; the original power calculations were based on total energy intake and body weight in pounds. Statistical power may have been especially impacted by the small sample size available for moderation analysis, as 7% of the original sample had to be excluded because the residential addresses could not be geocoded. Additionally, the moderator variables were generated using addresses from a single unvalidated dataset purchased from a commercial vendor. Although this is a frequently used approach to conducting geospatial analysis regarding community food environments, a recent systematic review investigating the validity of commercial food retailer data sources reported moderate concordance (0.42-0.44), sensitivity (0.59-0.65), and positive predictive values (0.49-0.62) of commercial address data relative to ground-truthed locations of food retailers.[32] Future research should use multiple data sources, validate the locations of food retailers, and conduct in-store audits to verify the availability of healthy food items within the stores. Additionally, as reported in a previous publication, we suspect underreporting in the 24-hour dietary recall data,[12] however the extent to which this would affect HEI-2010 scores is unknown. The HEI-2010 scores reported by HHHF trial participants at baseline are comparable to national surveillance estimates among women in the United States.[23] Taken together, results from this analysis suggest that a moderate-intensity coaching intervention focused explicitly on making health-promoting changes to home food

environments can result in participants altering their diets such that they are better aligned with federal dietary guidance, and that these modifications may result in reduced energy intake and weight loss. Future research is needed to develop low-cost interventions to improve dietary quality.

Figures and Tables

Table 7. Baseline Demographic, Socioeconomic, and Neighborhood-Level Characteristics of Participants in the Healthy Homes/Healthy Families Randomized Trial (N=349)

	Intervention Group (n=172) n (%) or mean ± SD		Control Group (n=177) n (%) or mean ± SD		*p*
Individual-Level Variables					
Age	50.5	± 7.98	49.8	± 8.18	.41
Race					.95
African American	146	(85.4)	149	(84.2)	
White	25	(14.6)	26	(14.7)	
Other	0	(0.0)	2	(1.1)	
Marital Status					.09
Married or living with partner	82	(47.7)	79	(44.6)	
Divorced, separated, or widowed	58	(33.7)	48	(27.1)	
Not married	32	(18.6)	50	(28.2)	
Employment Status					.62
Not employed, homemaker, student, or on disability	86	(50.0)	85	(48.0)	
Working full-time	61	(35.5)	58	(32.8)	
Working part-time	16	(9.3)	19	(10.7)	
Retired	9	(5.2)	15	(8.5)	
Education					.72
≤ Some high school	37	(21.6)	34	(19.2)	
High school or GED	65	(38.0)	62	(35.0)	
Some college/technical school	52	(30.4)	58	(32.8)	
≥ college graduate	17	(9.9)	23	(13.0)	
Household Income					.69
$10,000 or less	56	(33.1)	58	(33.5)	
$10,001 - $25,000	64	(37.9)	57	(33.0)	
$25,001 - $50,000	37	(21.9)	41	(23.7)	
$50,000 or more	12	(7.1)	17	(9.8)	
Number of Adults in Household					.29
None	16	(9.3)	21	(11.9)	
1	88	(51.2)	97	(55.1)	
2	49	(28.5)	35	(19.9)	
3+	19	(11.1)	23	(13.1)	
Number of Children in Household					.40
None	82	(47.7)	92	(52.3)	

	Intervention Group (n=172) n (%) or mean ± SD		Control Group (n=177) n (%) or mean ± SD		*p*
1	44	(25.6)	46	(26.1)	
2	33	(19.2)	19	(10.8)	
3+	13	(7.6)	19	(10.8)	
Neighborhood-Level Variables[a]					
Neighborhood Type					.31
Urban	99	(57.6)	109	(61.6)	
Rural	62	(36.0)	54	(30.5)	
Percent Living in Poverty (%)	32.4	± 14.7	32.4	± 14.1	.99
Median Income ($)	32,879	± 15,195	31,212	± 12,935	.29
Distance to Nearest Healthy Food Retailer (mi)	7.15	± 8.74	5.98	± 7.73	.20
Presence of Healthy Food Retailer within 1 Mile Buffer	31	± 19.25	48	± 29.45	.03
Number of Healthy Food Retailer within 1 Mile Buffer					.10
0	130	(75.6)	115	(65.0)	
1	20	(11.6)	30	(16.9)	
2+	11	(6.4)	18	(10.2)	

Note. P-values were generated using independent samples t-tests, chi-square, and Wilcoxon-Mann-Whitney tests. Missing values were excluded from all statistical tests.
[a] – Response missing for 25 participants whose residential addresses could not be geocoded.

Table 8. Impact of the Healthy Homes/Healthy Families Intervention on the Healthy Eating Index-2010 (HEI-2010) Total and Subcomponent Scores at 6 and 12-Month Follow-Up (N=349)

HEI-2010 Component (Max Score)	Baseline (N=349) mean ± SD	p^a	Change Baseline to 6-Months Follow-Up (n=287) mean ± SD	p^b	Change Baseline to 12-Months Follow-Up (n=263) mean ± SD	p^b
HEI-2010 Total Score (100)		.19		.008		.05
Intervention	51.09 ± 11.61		+3.41 ± 13.43		+1.73 ± 13.44	
Control	49.50 ± 11.09		+2.02 ± 12.26		+0.89 ± 12.66	
Total Fruit (5)		.86		.16		.21
Intervention	1.53 ± 1.63		+0.37 ± 1.85		+.005 ± 2.00	
Control	1.56 ± 1.59		+0.17 ± 1.95		-0.11 ± 1.81	
Whole Fruit (5)		.55		.12		.24
Intervention	1.39 ± 1.71		+0.37 ± 2.03		-0.02 ± 1.95	
Control	1.50 ± 1.69		+0.06 ± 1.81		-0.21 ± 1.78	
Total Vegetables (5)		.04		.008		.10
Intervention	2.58 ± 1.38		+0.37 ± 1.88		+0.37 ± 1.70	
Control	2.28 ± 1.33		+0.26 ± 1.91		+0.30 ± 1.70	
Dark-green and Orange Vegetables and Legumes (5)		.01		.08		.009
Intervention	2.08 ± 1.80		+0.00 ± 2.41		+0.31 ± 2.26	
Control	1.61 ± 1.65		+0.28 ± 2.15		+0.28 ± 2.23	
Total Grains (5)		.67		.15		.05
Intervention	0.98 ± 1.36		+0.33 ± 1.83		+0.39 ± 1.95	
Control	0.92 ± 1.33		+0.06 ± 1.61		-0.04 ± 1.64	
Whole Grains (5)		.64		.63		.25
Intervention	2.80 ± 2.58		+0.14 ± 3.26		+0.03 ± 3.10	
Control	2.67 ± 2.40		+0.24 ± 2.74		-0.05 ± 2.85	
Milk (10)		.39		.13		.55
Intervention	8.97 ± 1.77		-0.02 ± 1.94		-0.17 ± 2.01	
Control	8.81 ± 1.68		-0.05 ± 2.27		+0.23 ± 2.12	
Meat and Beans (10)		.99		.58		.70
Intervention	2.51 ± 3.02		-0.12 ± 4.29		-0.51 ± 4.27	
Control	2.51 ± 3.11		-0.17 ± 3.88		-0.22 ± 3.87	
Oils (10)		.98		.56		.95
Intervention	5.50 ± 2.58		+0.13 ± 3.52		+0.26 ± 3.35	
Control	5.51 ± 2.68		-0.01 ± 3.44		+0.27 ± 3.58	

HEI-2010 Component (Max Score)	Baseline (N=349)	p^a	Change Baseline to 6-Months Follow-Up (n=287)	p^b	Change Baseline to 12-Months Follow-Up (n=263)	p^b
Saturated Fats (10)		.01		.74		.38
Intervention	6.40 ± 2.67		-0.50 ± 3.50		-0.20 ± 3.58	
Control	5.62 ± 2.93		+0.22 ± 3.44		0.05 ± 3.79	
Sodium (10)		.12		.49		.96
Intervention	3.54 ± 2.75		+0.67 ± 3.80		-0.07 ± 3.61	
Control	4.00 ± 2.81		+0.07 ± 3.32		-0.35 ± 3.28	
Solid Fats, Alcoholic Beverages, and Added Sugars (20)		.57		.02		.12
Intervention	12.82 ± 5.23		+1.70 ± 4.99		+1.28 ± 5.27	
Control	12.51 ± 5.03		+0.90 ± 5.24		+0.76 ± 5.67	

Abbreviations SD=standard deviation

Note. Higher HEI-2010 total and subcomponent scores indicate better dietary quality.

[a] – *p*-values generated using independent samples t-tests to assess differences in HEI-2010 total and subcomponent scores between intervention and control group at baseline.

[b] – *p*-values generated using baseline-adjusted linear regression.

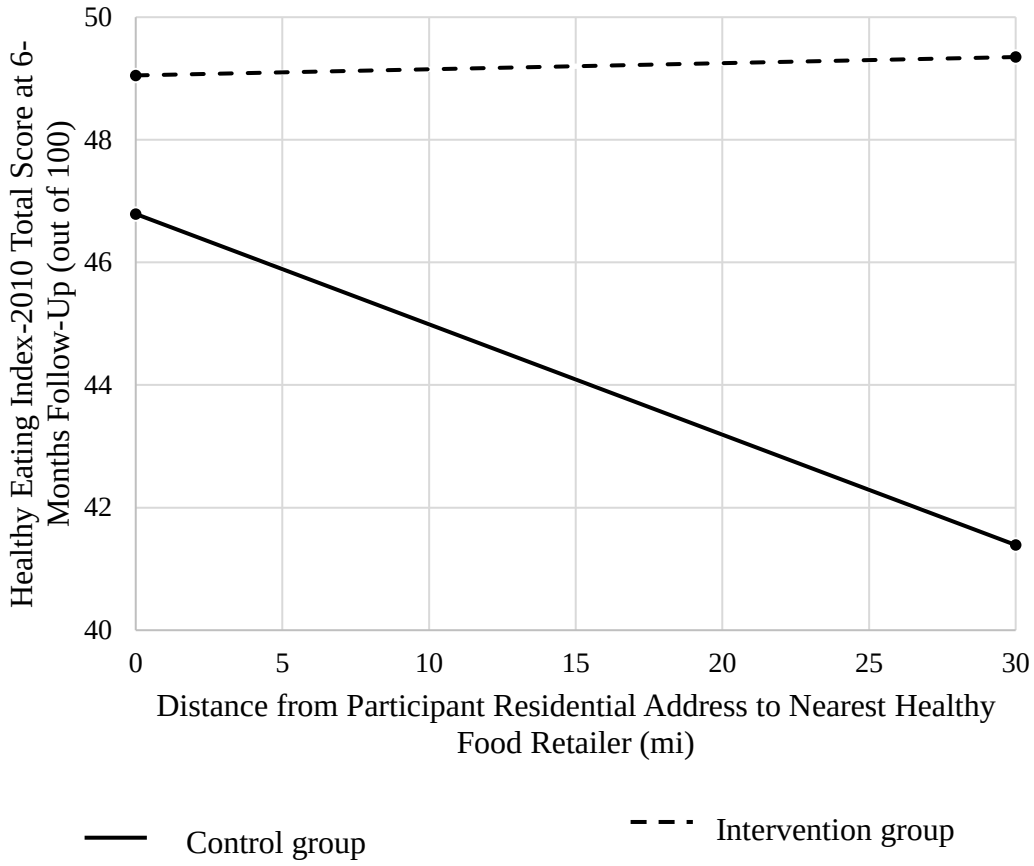
Table 9. Access to Healthy Food Retailers as a Moderator of the Efficacy of the Healthy Homes/Healthy Families Intervention to Improve Dietary Quality, as Measured by the Healthy Eating Index-2010 Total Score at Six Months Follow-Up (N=262)

	Measure of Access to Heathy Food Retailers		
	Proximity: Distance to nearest healthy food retailer (mi)	Availability: Presence of a healthy food retailer within 1 mi	Density: Number of healthy food retailers within 1 mi
	β (95% CI)	β (95% CI)	β (95% CI)
Intercept	46.79 (29.50, 64.08)****	42.76 (25.38, 60.38)****	43.20 (26.18, 60.22)****
Group	2.26 (-1.27, 5.79)	3.99 (0.73, 7.07)*	3.87 (0.87, 6.87)*
Access to Healthy Food Retailers when Group=0	-0.18 (-0.42, 0.07)	3.61 (-0.76, 7.99)	2.74 (0.69, 4.79)**
Access to Healthy Food Retailers when Group=1	0.01 (-0.24, 0.25)	2.64 (-2.36, 7.64)	2.63 (-0.73, 5.98)
Interaction term	0.18 (-0.13, 0.50)	-0.97 (-7.39, 5.44)	-0.11 (-3.93, 3.71)

†p<.10, *p<.05, **p<.01, ***p<.001, ****p<.0001

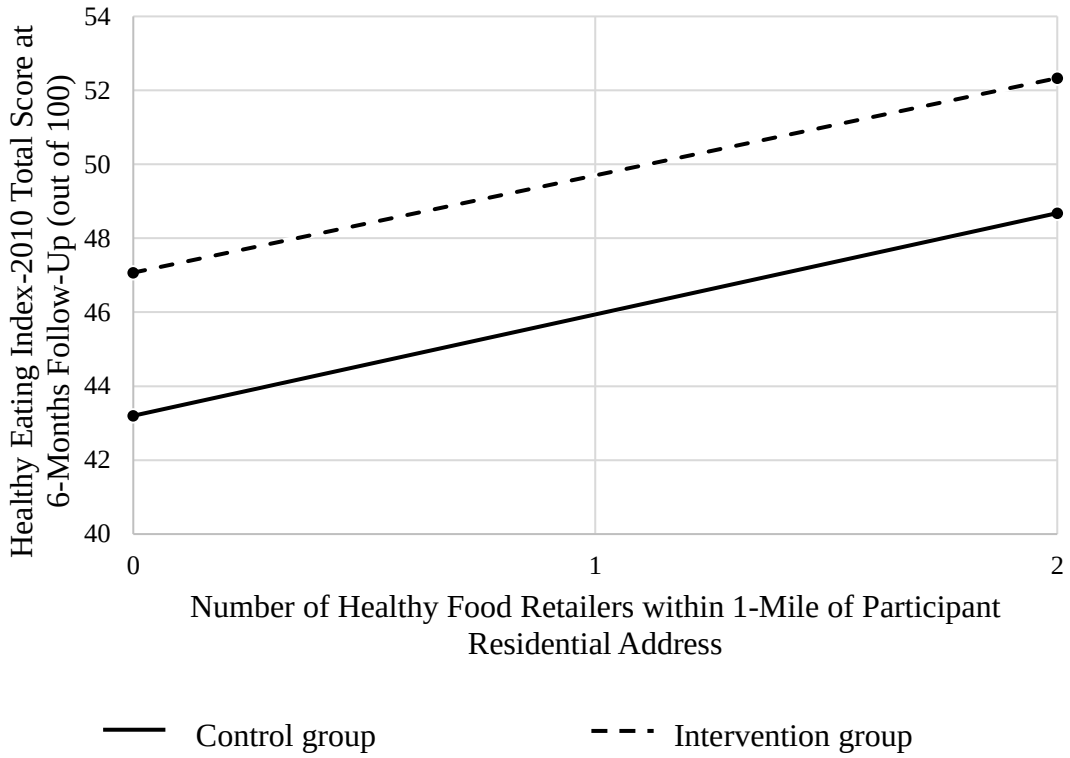
Note. Parameter estimates were generated using baseline-adjusted linear regression models, using the HEI-2010 total score at six-month follow-up as the outcome variable. Predictors included group, access to healthy food retailer, and an interaction term between group and access to healthy food retailer. Models were adjusted for mean-centered HEI-2010 score at baseline and the following covariates: age, marital status, employment status, educational attainment, annual household income, the number of adults in the household, the number of children in the household, an indicator variable for urban vs. rural, percent poverty within the census tract, and median household income within the census tract.

Figure 5. Distance to the Nearest Healthy Food Retailer as a Moderator of the Efficacy of the Healthy Homes/Healthy Families Intervention for Improving Dietary Quality (N=262)



Linear equations:
Control group: y=46.79-0.18x
Intervention group: y=49.05+0.01x
Note. Parameters estimates generated with baseline-adjusted linear regression models, using HEI-2010 total score at six-month follow-up as the outcome variable. Models were adjusted for mean-centered HEI-2010 score at baseline and the following covariates: age, marital status, employment status, educational attainment, annual household income, the number of adults in the household, the number of children in the household, an indicator variable for urban vs. rural, percent poverty within the census tract, and median household income within the census tract.

Figure 6. Number of Healthy Food Retailers within 1-Mile of a Participant's Home as a Moderator of the Efficacy of the Healthy Homes/Healthy Families Intervention for Improving Dietary Quality (N=262)



Linear equations:
Control group: y=43.2+2.74x
Intervention group: y=47.07+2.63x
Note. Parameters estimates generated with baseline-adjusted linear regression models, using HEI-2010 total score at six-month follow-up as the outcome variable. Models were adjusted for mean-centered HEI-2010 score at baseline and the following covariates: age, marital status, employment status, educational attainment, annual household income, the number of adults in the household, the number of children in the household, an indicator variable for urban vs. rural, percent poverty within the census tract, and median household income within the census tract.

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CHAPTER 5. Summary and Conclusions

The purpose of this dissertation was to conduct three research studies investigating various aspects of the relationship between food retail environments and dietary behavior in the United States. Ecologic approaches to health promotion suggest that structuring community food environments to facilitate healthy eating behaviors is an important component of chronic disease prevention efforts.[1-3] However, a large body of research has documented that many neighborhoods in the United States lack access to retailers of healthy foods[4-6] and have limited availability of healthy foods within their boundaries.[7,8] Low-income neighborhoods, those located in rural areas, and those with predominantly racial and ethnic minority residents are particularly underserved by healthy food retailers.[6] Increasing access to healthy food retailers is currently a developmental objective of Healthy People 2020,[9] and large-scale healthy food financing initiatives are underway to improve community retail food environments, in part through incentivizing the development of new retailers of healthy foods in underserved areas.[10-14] However, many questions remain as to the potential effectiveness of this approach to improving community environments. Specifically, this area of research is largely atheoretical, heavily reliant on cross-sectional observational studies, and has produced mixed results.

The purpose of this dissertation was to address these research gaps through the following aims:

- Specific Aim #1: Conduct a systematic review examining the impact of new openings of healthy food retailers on dietary behavior.

- Specific Aim #2: Investigate the relationship between an alternate measure of access to healthy food retailers and fruit and vegetable intake, and assess food acquisition behaviors as mediators of this relationship.
- Specific Aim #3: Assess to what extent access to healthy food retailers moderates the efficacy of a health promotion intervention to improve dietary quality.

Summary of Key Findings

Key findings from each chapter are summarized below and in Table 10. **Chapter 2** reported results from a systematic review assessing the impact of openings of new retailers of healthy foods on fruit and vegetable consumption among adults. This study resulted in three main findings. First, the methodological rigor of the included studies ranged widely, and relied heavily on pre-experimental and quasi-experimental designs. Second, we found some evidence of modest short-term increases in fruit and vegetable consumption among adults who chose to shop at the new retailer in the seven studies that used a repeated measures design. However, most of these estimates were not statistically significant. The extent to which these studies were adequately powered is unknown, as power analyses were not presented in any studies. Finally, the impact of these retailers on fruit and vegetable consumption among the general population of residents in the neighborhood, regardless of whether they began shopping there, remains unknown.

Taken together, these results suggest that opening a new retailer of healthy foods within a community may be necessary for increasing access to healthy foods, but may not be sufficient. Any improvements in dietary behavior are contingent upon consumers shopping at the new retailer to purchase their food. More research is needed to confirm these findings and explore the impact of these retailers on longer-term change in dietary

behavior, among children, and on other individual- (e.g., total caloric intake, body mass index, etc.) and area-level outcomes of interest (e.g., access to healthy foods, etc.).

Chapter 3 reported results from a mediation analysis assessing to what extent food acquisition behaviors mediated the relationship between distance to primary food store and fruit and vegetable consumption among a large national sample of adults who shop at a healthy food retailer as their primary store. Our original hypothesis was that people who reported that their primary food store was located farther from their home would report *lower* fruit and vegetable consumption, because we conceptualized this as a marker of poorer access within their neighborhood environments. Additionally, we hypothesized that this relationship would be explained by less frequent grocery shopping and lower home inventories of fruits and vegetables.

This study resulted in two key findings. First, we did not find evidence to support our hypothesis that the distance to primary food store would be negatively associated with fruit and vegetable consumption. Instead, our findings showed that distance was *positively* associated with fruit and vegetable consumption, such that people who reported greater distances to their primary food store reported *greater* fruit and vegetable consumption. Although the association was statistically significant, the effect size was very small and explained very little of the variability in the outcome. The second key finding was that greater home inventories of fruits and vegetables was a significant partial mediator of this relationship, although frequency of grocery shopping was not.

Taken together, these results suggest that distance to primary food store may not represent access, but may tap into other constructs, such as consumer preferences for food shopping. For example, individuals who consume large amounts of fruits and

vegetables may seek out retailers that offer large, high-quality selections of these products, which may be located farther from their homes, thus explaining the unexpected association between these variables. Additionally, results suggest that distance to primary food store may not influence how frequently consumers shop for food, but rather that consumers purchase more fruits and vegetables when they shop, thus explaining the mediating effect of home inventories.

Chapter 4 reports results of a moderation analysis examining to what extent three measures of access to healthy food retailers moderated the efficacy of the Healthy Homes/Healthy Families intervention for improving a secondary outcome of dietary quality. Because the intervention involved participants changing how they relate to their food environments by altering their food purchasing behaviors, we hypothesized that those with greater access to healthy foods would report a stronger intervention effect, as greater access would facilitate changes to their behavior.

This study resulted in two key findings. First, as expected, we found that poorer access to healthy food retailers was associated with lower dietary quality among control group participants, although the effect sizes tended to be small and most results were not statistically significant. Second, we found that the effect of limited access to healthy food retailers on dietary quality was attenuated among the intervention group, though these results were also not statistically significant. Finally, of the three tested measures of access to healthy food retailers, distance in miles to the nearest healthy food retailers showed the strongest potential moderating effect.

These results were contrary to our hypothesis that the intervention effect would be strengthened among participants living in environments that facilitate health-promoting

dietary change. Instead, we found that randomization to a behavioral intervention that involved, in part, modifying grocery shopping practices may have helped attenuate the negative effects of poor access to healthy food retailers on dietary quality, perhaps by altering participants' shopping behaviors.

Importance of Food Acquisition Behavior as a Cross-Cutting Theme

The importance of food acquisition behaviors emerged as a cross-cutting theme in this dissertation. Food acquisition behaviors refer to grocery shopping and other food procurement practices, including decisions about where to shop, frequency of shopping, types of foods purchased, dollar amount spent per shopping trip, and mode of transportation to the store. Although this dissertation was not designed to systematically assess food acquisition behaviors and their associations between food environments or dietary behaviors, each paper included results related to food acquisition, including the use of specific food retailers, frequency of grocery shopping, and home inventories of fruits and vegetables.

For example, in Chapter 2, a key finding was that the introduction of a new retailer into a community had the largest impact on fruit and vegetable consumption among consumers who *reported shopping at the new retailer*. In Chapter 3, a key finding was that *home inventories of fruits and vegetables* mediated the effect of proximity to primary food store on fruit and vegetable consumption among a large national sample of shoppers at healthy food retailers. In Chapter 4, a key finding was that an intervention to improve home food environments, in part through *modifying grocery shopping practices*, may have attenuated the negative impact of access to healthy food retailers on dietary quality.

These findings have important implications for both future research and practice. As has been noted in a recent systematic review, the dominant method of examining the impact of access to healthy food retailers on dietary behavior has been to estimate the magnitude and precision of the direct effect of various operational definitions of access to healthy food retailers on dietary outcomes.[15] Although this focus on direct effects is appropriate analytically for an emerging body of research, it is not reflective of the complex, as-yet poorly understood relationships between individuals and their environments. Furthermore, continued focus on quantifying the direct effects of environments on dietary behavior could be critiqued as suggesting that individual-level dietary behavior is a simple function of access to sources of healthy foods.

Results from this dissertation contradict simplistic understandings of how access to healthy food retailers influences diet. Results from each study in this dissertation suggest that instead of being passively exposed to their environments, individuals actively navigate them through their food acquisition behaviors. This finding is consistent with theoretical framework recognizing that access is multifaceted, encompassing more than simple availability or accessibility to a healthy food retailer.[15,16] According to these frameworks, access also includes the affordability of the products sold and the acceptability of these products to patrons, and the ability of the retailer to accommodate consumer shopping needs.[15,16] The importance of food acquisition behaviors is also consistent with current research, indicating that consumer decisions about where to purchase food and how to navigate their food environments are complex and relate to convenience, daily commute patterns, perceived quality of products sold, and other considerations.[17-19]

Strengths & Limitations

This dissertation had several limitations. Study-specific limitations are discussed in depth in Chapters 2-4 and are summarized in Table 11. In addition to these study-specific limitations, the dissertation as a whole had important limitations. The major limitation of this dissertation is that it focused on access to healthy food retailers as a feature of the food retail environment in participant's residential neighborhoods. The impact of other features of the community food environment (e.g., access to other categories of retailers, including restaurants, dollar stores, convenience stores, and corner stores) and features of the in-store environment (e.g., the quantity, quality, and price of specific food products sold) were not investigated as part of these studies. Additionally, though this approach is consistent with most of the previously published literature,[15] consumers may obtain food from places outside of their residential neighborhoods, including areas around their schools, workplaces, or along their daily commute routes.[20] The ideal method of measuring access to healthy food retailers in this broader environment is to use GPS tracking to identify an individual's daily activity space,[20] but this approach was not feasible for this dissertation.

The primary strength of this dissertation project was that it answered novel and innovative research questions. At the time that these studies were conceptualized, no known systematic reviews had synthesized research findings regarding the impact of openings of new healthy food retailers on dietary behavior or had examined food acquisition variables as mediators of the impact of community food environments on dietary behavior. Additionally, only two known studies had assessed food acquisition

behaviors as potential moderators of the efficacy of behavioral interventions to improve dietary behavior,[21,22] although others have been published since that time.[23-25]

Additionally, a feature of this dissertation was that it did not address a single, cohesive research question. Instead, the dissertation explored the effect of food retail environments on dietary behavior, using multiple conceptualizations of the food retail environment (e.g., initiatives to improve access to healthy food retailers, objectively distance to nearest healthy food retailer, self-reported distance to primary food retailer) and dietary behavior (e.g., fruit and vegetable intake, dietary quality). Though this approach allowed for a nuanced, multifaceted approach to studying these relationships, it limits our ability to draw strong conclusions across studies.

Implications for Public Health Practice

Results from this dissertation have implications for public health initiatives to increase access to healthy foods throughout the United States.

1. Exercise caution in relying solely on opening new retailers of healthy foods in limited-access communities as a chronic disease prevention strategy.

In light of the well-documented disparities in access to healthy foods in many communities throughout the United States,[4,6,26] continued efforts are needed to increase access to healthy food retailers nationwide.[9] One approach to achieving this goal, and the focus on Chapter 2 of this dissertation, is to open new retailers of healthy foods into limited-access communities. Although this approach has been a component activity of the Healthy Food Financing Initiative,[10] and other similar state-level programs,[11-14] the evidence base regarding this approach remains weak. Few studies have tested the potential impact of these initiatives on dietary behavior or other chronic disease-relevant

outcomes, and those that have relied heavily on pre- and quasi-experimental designs that have limited ability to causally attribute any change in the outcome to the new retailer itself.

Furthermore, although we did find some evidence of increased fruit and vegetable consumption, the effect sizes were modest in size, mostly non-significant, occurred in the short-term, and appeared to be limited to individuals who began shopping at the new retailer. If this strategy is to be a continued component of chronic disease prevention strategies, resources need to be invested in identifying and implementing marketing and effective outreach efforts to encourage residents of the new community to use the new retailer for their grocery shopping needs. Interdisciplinary partnerships between the business community and marketing and communications professionals may be useful in planning these activities, insofar as they fall outside of the areas of competency of public health professionals.

Additionally, though not empirically assessed in this dissertation, opening a new retailer of healthy foods in a community is an expensive, resource, and time-intensive endeavor, and the success of these initiatives is likely directly tied to their economic sustainability. If limited-access communities lack the economic base to sustain such a retailer, this approach is unlikely to be successful, and alternative approaches to increasing access to healthy food retailers should be considered.

2. <u>Consider implementing environmental interventions to increase stocking of healthy foods in small food stores in limited-access communities as a complementary or alternative approach to opening new retailers of healthy foods.</u>

Another approach to increasing access to healthy food retailers is to partner with food retailers that are ubiquitous in limited-access communities throughout the United States, such as dollar stores, convenience stores, corner stores, bodegas, and *tiendas*, to equip them to sell food products aligned with *Dietary Guidelines for Americans*.[6,27,28] In-store audits have found that these types of small food stores tend to sell energy-dense food items as compared to healthier alternatives.[29] Small food store interventions typically involve partnering with store owners to increase stocking of healthy food items coupled with other changes to the in-store food environment, such as promoting healthy food options through marketing and discounts, offering taste tests and cooking demonstrations, or general nutrition education in the store.[28,30]

According to a recent systematic review, small food store interventions are supported by a larger and methodologically stronger body of research as compared to new retailer openings, and show promise for achieving intended outcomes.[30] Formative and process evaluations have shown that these initiatives are acceptable to small food store owners,[31] are feasible,[32,33] and can be implemented with fidelity.[32-34] Outcome evaluations have documented increased stocking of healthy foods,[34,35] purchasing of healthy foods,[36] and improved dietary behaviors.[37] These results suggest that these initiatives have a stronger evidence base supporting their use, and may be used as a complementary or alternative approach to building new retailers of healthy foods within a limited-access community. By capitalizing on the existing food retail infrastructure, these initiatives are likely to be less costly and may be more economically sustainable in the longer term as compared to building new retailers of healthy foods.

3. Implement evidence-based interventions at other levels of the social ecology in addition to increasing access to healthy food reatilers at the community level.

One key finding from this dissertation is that consumers are not passively exposed to their food retail environments, but instead actively navigate them through their food acquisition behaviors. As a result, initiatives focused solely on increasing access to healthy food retailers, either through opening new retailers or healthy corner store interventions, may be necessary for achieving behavior change, but are likely insufficient. Any dietary change attributable to these initiatives will be a result of intermediary proximal behavior change.

For example, in order for dietary change to be achieved, consumers must begin shopping at the retailer offering healthy food options, purchasing the healthier food items over other competing items in the store, and preparing these purchases in their home at home. Each intermediary step could be subject to other influences at the community-, store-, household- and individual-levels. Efforts to build new retailers of healthy foods or encourage existing retailers to stock more healthy food options may be strengthened if they were accompanied by:

- Community-level interventions to address different components of access (e.g., infrastructure changes to increasing methods of transportation to the new retailer or financial incentives or subsidies to increase the affordability of healthy products available to consumers).[38,39]
- Behavioral design interventions, which refers to modifications to the in-store environment to ensure that the healthy food items are attractively and conveniently

placed within the store, well marketed and promoted, and that the selection of healthy food items offered is culturally appropriate for consumers' needs.[30,32,35]

- Family-level interventions to motivate consumers to improve their home food environments by modifying their grocery shopping and food preparation practices.[40-43]
- Individual-level interventions focused on general nutrition education.[44,45]

Although each of these intervention approaches have been shown to be effective individually, research testing the additional benefits of intervening at multiple levels of the social ecology to improve dietary behavior remains scarce, due in part to the considerable practical challenges to implementing and evaluating multilevel interventions.[46] However, despite the limited evidence base, this approach is supported by the Social Ecological Model and other dominant theoretical frameworks for health promotion.[1-3] Implementing and evaluating multilevel interventions to improve dietary behavior would make a meaningful contribution to chronic disease prevention theory, research, and practice.

Directions for Future Research

Recommendations for future observational and experimental research are summarized below.

<u>Observational Research</u>

1. <u>More research is needed to build and test theories of how community food retail environments impact dietary behavior and chronic disease risk.</u>

Although multiple theories of health promotion have been used to identify characteristics of environments as determinants of health behavior,[1-3] very few studies

have proposed and tested theoretical frameworks focused on how environments influence diet.[47] Specifically, the operational definitions of access that are most important, the mechanisms through which environments affect dietary behavior, and the populations that are most influenced by their food environments remain largely unexplored.

This field of research would benefit from four major activities. First, qualitative research exploring how consumers perceive and navigate their community food environments may assist this field in developing theories that can be empirically tested in subsequent research.[48] Second, a meta-analysis of the cross-sectional observational literature, synthesizing the various operational definitions of access to healthy food retailer that have been assessed in relation to dietary behavior, and their results, is needed. Third, more research is needed to assess food acquisition behaviors as mediators of the relationship between dietary intake. These studies could assess the mediators used in this dissertation (e.g., frequency of shopping for fruits and vegetable and home inventories of fruits and vegetables) or other mediators yet to be examined (e.g., store type, dollar amount spent on groceries, etc.) Finally, future research exploring potential moderating variables is needed. This dissertation analysis assessed the extent to which rurality moderated the relationship between distance to primary food store and fruit and vegetable consumption, but other potential moderators worth exploring may include a measure of poverty (e.g., receipt of SNAP benefits) or car ownership.[49]

2. <u>Descriptive research regarding food acquisition behaviors in the United States is needed.</u>

Descriptive research is needed regarding food acquisition behaviors in the United States. National prevalence estimates of the frequency of grocery shopping, distance

traveled to store, types of stores patronized, dollar amount purchased, as well as qualitative and quantitative data regarding how consumers make decisions regarding grocery shopping for their households is needed. This information may provide useful data that will help clarify unanswered questions in this area of research, including what retailers to focus on (e.g., presence of specific store types or overall composition of retailers within a geographic area), what environments to study (e.g., residential environments vs. activity spaces), what measures of access to use (e.g., availability, accessibility, affordability, etc.), and potential covariates to control for, all of which have been inconsistently operationalized.

Intervention Research

3. Increase methodological rigor and consistency of intervention research.

More research is needed to assess the dietary impact of interventions to improve community food environments by opening new retailers of healthy foods. In particular, future studies of greater methodological rigor and standardization would advance this field of research and facilitate meta-analytic synthesis of results. Specifically, using designs with a pre-test, comparison groups and probability sampling methods would help to reduce bias and strengthen the case for causal attribution of change in the outcome to the opening of a new retailer of healthy foods. Additionally, the strongest outcome measures possible should be used. Though time consuming and expensive to use, when resources are available, multiple 24-hour dietary recalls should be used, as this method is considered to be the gold standard for collecting self-reported dietary data. When this data collection method is not feasible, food frequency questionnaires with known psychometric properties (e.g., National Cancer Institute's Fruit and Vegetable Intake

Screener) or those used in surveillance research (e.g., Behavioral Risk Factor Surveillance System Fruit and Vegetable Intake Screener) are recommended to facilitate comparisons across studies, with national estimates, and with secular trends over time. The use of very brief (single or two-item) instruments and those assessing self-reported retrospective change is discouraged due to concerns about their validity and social desirability bias, and recall bias.

4. Explore the impact of these initiatives on other individual- and area-level outcomes.

Future experimental research should also focus on outcomes besides dietary behavior, such as implementation or process evaluation results (e.g., extent to which the retailer reached its intended beneficiaries, revenue trends, changes in purchasing patterns, etc.), change in area-level outcomes (e.g., availability of healthy foods within the community), or individual-level outcomes (e.g., dietary quality, total energy intake, body mass index). Although many articles reported these results, summarizing them was beyond the scope of the systematic review summarized in Chapter 2. However, future reviews should summarize the extent to which openings of new retailers improve other outcomes of interest in order to contribute to more comprehensive understanding of the expected effects of this strategy.

This area of research may also benefit from investigation into the potential unintended consequences of opening new retailers of healthy foods, especially large retailers including full-service supermarkets, superstores or supercenters, and wholesale clubs, in low-income or limited-access communities, such as impacting the socioeconomic opportunities available to residents. For example, only one known study has investigated the potential impact of these retailer openings on the socioeconomic

status of residents.[50] Additional research regarding the impact of these initiatives as a mechanism of gentrification (e.g., by driving up property values and displacing residents), for potential impacts on the local economy (e.g., by displacing existing retailers), or improving socioeconomic opportunity (e.g., by creating jobs) warrants additional research.

5. Investigate the sustainability and cost-effectiveness of these strategies

Although beyond the scope of this dissertation, research regarding the economic sustainability and cost-effectiveness of introducing new retailers of healthy foods into a community may help clarify the role of new retail as part of a broader agenda to improve local food environments. For example, results regarding the economic sustainability of these initiatives may indicate how likely these initiatives are to be sustained past the initial grant funding period, to identify the types of retailers that are most likely to be sustained, and to develop best practices to increase the likelihood of sustainability. Results from cost-effectiveness analyses could be similarly used to compare new retail with other structural interventions to increase access to healthy foods (e.g., subsidies, in-store intervention to improve existing food retailers) to help allocate scarce resources for health promotion and chronic disease prevention most effectively.

Conclusion

This dissertation addresses gaps in scientific understanding of the relationships between food retail environments and dietary behaviors in the United States. Although a large body of research has documented that many neighborhoods in the United States lack access to healthy food options, the associations between access to healthy foods and dietary behavior remains an area of active research. Future research focused on (1) the elements of local food environments that influence dietary behavior, (2) the mechanisms

through which such associations operate, and (3) whether these environments can be altered to improve population-level dietary behavior and prevent chronic diseases will help strengthen chronic disease prevention and control efforts in the US.

Figures and Tables

Table 10. Summary of Key Findings from Dissertation Analyses

Chapter	Specific Aim	Hypothesis	Key Findings	Implications
2	Conduct a systematic review examining the impact of new openings of healthy food retailers on dietary behavior.	N/A	• Methodological rigor of studies varied widely. Heavily reliant on pre- and quasi-experimental designs. • Some evidence of short-term increases in intake among adults who choose to shop at the new retailer, but effect sizes were small. • Change among residents of the community (regardless of whether or not they used the new retailer) was unclear.	• Improving access to healthy food retailers may improve fruit and vegetable consumption among people who choose to shop there.
3	Investigate the relationship between self-reported distance to primary food store and fruit and vegetable intake among a large national sample of shoppers at healthy food retailers, and determine to what extent food acquisition behaviors mediate this association.	• People who report shopping at a food retailer located farther from their homes will report lower fruit and vegetable intake. • Less frequent grocery shopping and lower home inventories of fruits and vegetables will	• Hypotheses were not supported. • Distance to primary food store was positively associated with F&V intake among large national sample of healthy food shoppers, but effect size was small and distance explained very little of the variability in the outcome.	• People whose primary food stores are located farther from their homes eat more fruits and vegetables because they purchase more of them (explaining higher home inventories), but not because they shop there more frequently. • It is possible that people who value fruits and vegetables or healthy

Chapter	Specific Aim	Hypothesis	Key Findings	Implications
		mediate this association.	• Effect was mediated by home inventories of fruits and vegetables, but not shopping frequency.	eating seek out retailers that offer these products, explaining the unexpected positive association.
4	Assess to what extent access to healthy food retailers moderates the efficacy of a health promotion intervention to improve dietary quality.	• People with greater access to healthy food retailers will report a stronger intervention effect as compared to those who live in areas with less access.	• Hypotheses not supported. • Though most results were not statistically significant, greater access to healthy food retailers seemed to be associated with higher HEI-2010 scores among control participants. Effect of environment on diet was smaller among intervention participants. • Some measures of access to healthy foods showed a stronger moderating effect than others, with distance to the nearest healthy food retailer showing the strongest effect.	• Participation in Healthy Homes/Healthy Families may have attenuated the impact of the food environment on dietary quality.

Table 11. Study-Specific Strengths and Limitations

Chapter	Specific Aim	Strengths	Limitations
2	Conduct a systematic review examining the impact of new openings of healthy food retailers on dietary behavior.	• First known study to synthesize this body of research.	• Potential publication bias • Potential incomplete retrieval of relevant articles from keyword search strategy • Meta-analysis was not feasible
3	Investigate the relationship between self-reported distance to primary food store and fruit and vegetable intake among a large national sample of shoppers at healthy food retailers, and determine to what extent food acquisition behaviors.	• Large national dataset • Stratification by rurality • Strong outcome measure (relative to other brief screeners)	• Cross-sectional dataset • Measure of distance to primary food store was created for this study with unknown psychometric properties • Could not account for availability of healthy food options within participants' communities
4	Assess to what extent access to healthy food retailers moderates the efficacy of a health promotion intervention to improve dietary quality.	• Two-group randomized design • Gold-standard outcome measure (multiple 24-hour dietary recalls)	• Food retailer address data acquired from single source • Addresses were not verified using ground-truthing procedure • Suspected underreporting of dietary intake.

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