Title Page

**Where You Shop and Neighborhood Access to Fruit and Vegetables are Associated with Self-rated and Cardiometabolic Health**

by

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**Abstract**

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**Where You Shop and Neighborhood Access to Fruit and Vegetables are Associated with Self-rated and Cardiometabolic Health**

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University of Pittsburgh, 2020

**Abstract**

**Introduction:** The food retail environment may partially explain racial and ethnic disparities in diet and health. However, there is limited understanding of how specific aspects of the food retail environment and food shopping locations may be associated with cardiometabolic (blood pressure, HbA1c, cholesterol, BMI) and self-rated health in low-income minority populations. **Methods**: We report on 459 individuals from two low-income predominantly Black neighborhoods who participated in a household interview and blood draw in 2018 as part of the Pittsburgh Hill/Homewood Research on Neighborhoods and Health (PHRESH) study. We used logistic regression to examine associations between 1) perceived fruit and vegetable availability, quality, and price, and 2) primary food shopping store type, and reason for shopping there and 3) frequency of shopping at stores with low or high access to healthy foods, with cardiometabolic and self-rated health. **Results:** On average,participants were 60.7 years old (SD=13.9); 81.7% female; and 80.4% overweight/obese. After sociodemographic adjustment, both higher perceived accessibility and affordability of fruits and vegetables within one’s neighborhood were associated with lower odds of high blood pressure (OR:0.47, 95%CI:0.28-0.79; OR:0.59, 95%CI:0.36-0.96, respectively), as well as lower odds of poor self-rated health (OR:0.59, 95% CI:0.39-0.90; OR:0.62, 95%CI: 0.41-0.94, respectively). Primary food shopping at a discount grocery store compared to a full-service supermarket was associated with lower odds of being overweight (OR:0.51, 95%CI:0.26-0.99). Shopping often versus rarely at stores with low access to healthy foods was associated with increased odds of high total cholesterol (OR:3.52, 95%CI:1.09-11.40). **Conclusion:** These results suggest thatperceived accessibility and affordability of healthy foods and store type used for primary food shopping are important correlates of cardiometabolic risk factors in low-income minority populations. Further research should look towards understanding how direct food choices made at stores impact cardiometabolic outcomes within this population. These results are significant to public health because they show that food stores beyond supermarkets may be important options for accessing healthy food among this population.

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# Introduction

## Cardiovascular Disease

Cardiovascular disease (CVD) produces a large health and economic burden in the United States and is the leading cause of death in the US.1 The American Heart Association defines CVD as a number of conditions comprising of coronary heart disease, heart failure, stroke, hypertension, heart attack, heart failure, and arrhythmia.1,2 CVD is prevalent in 48% of US adults over the age of 20, and Blacks are more likely to die from CVD and have twice the avoidable death rate compared to Whites.1,3 Racial differences in socioeconomic status (SES) are thought to partially explain the disparities in cardiovascular disease risk.4

### Cardiometabolic Risk Factors

Cardiometabolic risk factors have a large influence on lifetime risk of CVD, with risk increasing as more risk factors are gained.5,6 From 1980 to 2000, reductions in cardiometabolic risk factors resulted in a 44% decrease in coronary heart disease (CHD) deaths.7 Body mass index (BMI), hemoglobin A1c (HbA1c), total cholesterol, high density lipoprotein (HDL) cholesterol, and blood pressure (both diastolic and systolic) are all modifiable risk factors related to CVD and CHD.1,8–10

Higher values of BMI indicating a weight status of overweight and obese are associated with an increased lifetime risk of CVD and a reduced median survival compared to normal weight.6 Additionally, improvements in BMI can result in improvements of other cardiometabolic risk factors, specifically HbA1c, systolic blood pressure and HDL.11 Contrary to other risk factors, a lower value of HDL is related to higher CVD and CHD risk.1,9 An increase in total cholesterol is associated with an increased lifetime risk for CVD and CHD and shorter median survival for both men and women.6 Both systolic blood pressure (SBP) and diastolic blood pressure (DBP) are significantly related to CVD risk and median survival in both men and women, with higher values correlating to higher risk.6,8 Additionally, high blood pressure is a major risk factor for stroke.1 Lastly, higher values of HbA1c are related to higher CVD risk.8 HbA1c is used to diagnose diabetes (>6.5%) and provides significantly better discriminatory power than self-reported diabetes diagnosis.8,12 Importantly, HbA1c is still associated with CHD risk even among those who are non-diabetic.10

#### Disparities in Cardiometabolic Risk Factors

Disparities in cardiometabolic risk factors exist by both income and race. Low socioeconomic status (SES) has been shown to be associated with high levels of obesity and poor nutritional health.13,14 The prevalence of cardiometabolic risk factors is higher among Blacks than Whites which contributes to a higher risk of cardiovascular disease for Blacks.5 High blood pressure, also known as hypertension, is more prevalent among non-Hispanic Blacks (40.3%) compared to non-Hispanic whites (27.8%), non-Hispanic Asians (25.0%), and Hispanics (27.8%) in the United State adult population.1,15 The prevalence of undiagnosed diabetes and prediabetes is highest among non-Hispanic Blacks.16 Additionally, Non-Hispanic Blacks have a higher mortality compared to non-Hispanic Whites.17

The neighborhood environment often perpetuates socioeconomic and racial disparities, as Blacks are four times more likely to live in low SES neighborhoods than Whites, and neighborhood SES affects the prevalence of obesity, diabetes, and hypertension.18–20 The Jackson Heart Study, a longitudinal, exclusively Black cohort in Jackson, MS, found that Black women living in socioeconomically disadvantaged neighborhoods had higher prevalence of metabolic syndrome compared to those not living in socioeconomically disadvantaged neighborhoods.21

Diet is a modifiable risk factor that affects cardiometabolic risk factors. Using 24-hour dietary recalls, a cross sectional study of 2,121 participants found that improved diet quality was associated with lower glucose (p=0.03) and lower BMI (p=0.02)22. A summary of systematic reviews and meta-analyses published in 2019 found that differing dietary patters such as Mediterranean and vegetarian are associated with improved cardiometabolic risk factors23. Researchers have found that poor diet was associated with an increased risk of diabetes, even after adjusting for BMI.22–24Increased intake of fruits and vegetables is associated with a reduction in cardiovascular disease and cancer.25 Women eating greater than five fruit and vegetable servings are significantly more likely to maintian a healthy BMI despite living in an envionrment that encourages unhealthy eating and physical inactivity compared to those eating less.26,27 Poor diets and diet-related diseases disproportionately affect those with lower SES.13

## Self-Rated Health

Self-rated health is a valid and reliable measure of general health, generally measured with a single survey question in which health is rated on a 5-point scale from excellent to poor.28 Non-Hispanic Blacks have lower self-reported health statuses and a higher mortality compared to non-Hispanic Whites.17

Self-rated health is a strong predictor of mortality, and a valid indicator of overall health even after adjustment for key covariates.17,29,30 A systematic review found that people with poor self-rated health have a two times higher mortality compared to people with excellent self-rated health.31 Additionally, the incidence of fatal and non-fatal CHD is strongly associated with self-rated health even upon controlling for sociodemographics and confounders. Self-rated health has been shown to be useful as a complementary outcome alongside more traditional cardiometabolic risk factors when predicting CVD and CHD.30

## Food Enviornment

Improving the neighborhood food environment may positively influence dietary behaviors which, in turn, can postiviely affect cardiometablic health.32,33 Food environments can be conceptualized by three main dimensions33: 1) Availability, the adequacy of the supply of health food such as large selection and high quality of fruits and vegetables; 2) Accessability, the location of food supply and ease of getting to that location; and 3) Affordability, the prices of food and people’s perceptions of worth relative to cost.

Supermarkets are highly frequented for food shopping and acquisition by U.S. households, and as retail venues, they are considered to provide access to healthy food to enable healthy food choices.34,35 A significant amount of research has been conducted to understand the effects that supermarket accessibility has on diet and disease. Low-access communities, commonly known as food deserts, lack healthy food sources such as supermarkets, supercenters, or large grocery stores.36

Many cross-sectional design studies have found that adults with better access to supermarkets tend to have better diets.13 The Atherosclerosis Risk in Communities (ARIC) study, which had 10,623 participants, found that for Black American’s, fruit and vegetable intake increased by 32% for each additional supermarket in the census tract (RR=1.32, 95%CI: 1.08, 1.06). This association was attenuated and non-significant for White American’s (RR=1.11, 95%CI=0.93, 1.32).37 Additionally, a study which included 266 Black women living in Detroit found that those whose shopped at supermarkets and specialty stores consumed fruits and vegetables more often than those who shopped at independent grocers.38

Another large US cohort cross-sectional study, the Multi-Ethnic Study of Atherosclerosis (MESA) study, found that participants without a supermarket within a mile of their home were 25% less likely to have a healthy diet than those with a supermarket within a mile of their home (relative probability = 0.75, 95%CI: 0.59, 0.95). This association was seen after adjustment for sociodemographics.39 A similar study by Moore et al. (2008) which surveyed 5,774 residents in North Carolina, Maryland, and New York found that those who live in areas with high supermarket density had better perceptions of healthy food availability compared to those living in areas with lower densities of supermarkets (p<0.05).40

While the presence of supermarkets has been associated with improved perceptions of access to healthy foods and greater consumption of healthy foods, the presence of corner stores, gas stations, and small independent stores has been shown to be associated with worse access and perceptions of healthy foods and high access to unhealthy foods.34,40–42 Additionally, a 2018 review of current literature highlighting evidence on the association between neighborhood environment and type 2 diabetes found conclusive evidence supporting the fact that populations in neighborhoods with more convenience stores and fast food outlets have increased incidence and prevalence of diabetes.43

### Food Environment Inequities

Disparities in diet related chronic diseases and obesity rates are thought to be attributed, in part, to lack of access to affordable and healthy foods and the inequities that exist in the food environment based on race and income by neighborhood.14 Individuals in predominantly minority neighborhoods experience greater environmental barriers towards maintaining a healthy diet compared to individuals in mixed-race neighborhoods.44 Large racial disparities exist in the availability of supermarkets in neighborhoods, even when controlling for neighborhood level income.14 Predominantly Black neighborhoods have fewer supermarkets compared to predominantly white neighborhoods.14,45,46 Socioeconomic disparities also exist, as one study found that Black women with higher per capita incomes are more likely to shop at supermarkets and thus have increased fruit and vegetable intake.38 Additionally, fresh produce quality and availability of healthy alternatives to unhealthy foods has been shown to decline as level of neighborhood deprivation increases.34 It is postulated that these neighborhood differences by SES in availability of food and economic barriers towards purchasing food may partially explain why groups with lower SES have poorer diets and more diet-related diseases than groups in higher SES.13

### Initiatives to Improve the Food Environment

Due to the inequities in food environment based on race and income, Pennsylvania created the Fresh Food Financing Initiative (FFFI) in 2004 which provides money to open supermarkets and grocery stores in underserved urban and rural communities.47 The ultimate aim of the initiative is to reduce the incidence of diet-related diseases such as obesity, heart disease, and diabetes.47 As of April 2020, the FFFI has planned to have opened 80 stores and provided fresh food for around 400,000 people, primarily those of low SES and minorities.48

In 2011, the United States created the Healthy Food Financing Initiative (HFFI) which was modelled after the Pennsylvania initiative.48 400 million dollars was allocated towards opening supermarkets and grocery stores with fresh produce in urban and rural food deserts with the aim to eliminate these food deserts in 7 years.48

While prior evidence suggests that the opening of supermarkets and grocery stores in low resource communities should be effective in improving diet and decreasing diet-related diseases, longitudinal and natural experimental research on these initiatives provides mixed results on their effectiveness. A pilot study in Philadelphia used a quasi-experimental longitudinal design to evaluate the impacts of opening a supermarket in a predominantly Black community through the FFFI. Over a four-year period, the intervention neighborhood had a significant increase in perceptions of healthy food accessibility compared to the control neighborhood (p<0.01). However, there were no significant improvements in BMI or fruit and vegetable intake as a result of the new supermarket.49

The Coronary Artery Risk Development in Young Adults (CARDIA) study (N=5115) used 15-year longitudinal data to understand the influence of neighborhoods supermarkets on diet quality and fruit and vegetable intake. Greater supermarket availability and grocery store availability were overall unrelated to dietary quality and fruit and vegetable intake.50 Zhang et al. (2017) drew from a sample of participants from the Kaiser Permanente Northern California Diabetes Registry (N=434,806; 2007-2010) to understand the association between the gain or loss of neighborhood supermarket presence and changes in HbA1c. Supermarket loss was associated with worse HbA1c values for participants with good, moderate, and poor glycemic control at baseline. Supermarket gain was marginally associated with better HbA1c values only among patients with close to normal HbA1c values at baseline.51

There are many hypotheses as to why improving the food environment may not be effective at decreasing diet related diseases and improving diet. First, opening a new store may have limited influence on changing food purchasing behaviors, as people may be accustomed to buying the same foods even upon changing stores.52 Also, even if people have access to healthy foods, there is a challenge in keeping these healthy foods affordable, and unhealthy foods are still widely available for purchase for a low price at full-service supermarkets.42,52 Lastly, people may be accustomed to shopping at a specific store and might not change their habits to shop at a new supermarket that opens in their neighborhood.49

## Prior Research on Food Environment and Health Outcomes

Prior research is limited towards primarily understanding the effects of shopping at specific store types and neighborhood food environment on diet and self-reported health and obesity outcomes rather than specific cardiometabolic outcomes which are directly associated with heart related diseases. Zenk et al. (2005) collected information on the name and location of where Black women shoppers in Detroit purchased most of their food (N=266). They found that those who did their primary shopping at supermarkets and specialty stores consumed 1.22 and 2.37 times, respectively, more fruits and vegetables daily compared to those who did their primary shopping at independent grocers after adjusting for covariates (p<0.001 and p<0.05, respectively). Additionally, they found that more positive perceptions of selection and quality of fresh produce were positively related to frequency of fruit and vegetable intake (p<0.05).38

The ARIC study conducted a cross sectional analysis on a US cohort of adults examining food retail environment effects on the cardiometabolic outcomes of measured obesity and hypertension (N=10,763). Census tracts and national geographic boundaries were used as proxies for neighborhoods. Compared to those who lived in neighborhoods without any supermarkets, those who lived in a neighborhood with at least one supermarket had a 9% lower prevalence of overweight, 24% lower prevalence of obesity, and 12% lower prevalence of hypertension (p<0.05). The availability of convenience stores was associated with an increased prevalence of overweight, obesity, and hypertension (p<0.05). One of the main limitations of the study was that they only looked at store type geographic availability and not usability which could result in misclassification if the census tract does not represent the area where individuals shop for food or does not accurately represent neighborhood.53

Another cross-sectional analysis examined the association between food store usage and frequency of obtaining healthy and unhealthy foods in a primarily low-income Black cohort in East and West Baltimore City (N=175). Unhealthy foods were more frequently purchased by corner store shoppers compared to supermarket shoppers (p<0.01). However, there was no significant differences in the purchasing of healthy foods between corner store and supermarket shoppers (p=0.52).41 Data from the New Orleans Behavioral Risk Factor Surveillance System was used to understand the association between the urban food environment and BMI (calculated using self-reported heights and weights) (N=3,925). Neighborhood was defined as a 2-km distance in all directions around each participant’s census tract. Supermarket access was found to be inversely associated with obesity while fast food restaurant and convenience store access was found to be directly associated with obesity. Similarly, to the ARIC study, one of the main limitations was that only store accessibility was examined and not store usability. Additionally, misclassification of obesity status could have occurred due to only using self-reported measurements.54

Lastly, the NEWPATH (Neighborhood Environments in Waterloo Region: Patters of Transportation and Health) study assessed associations between food store usage with diet and BMI (self-reported weight and height), and self-assessed weight circumference (N=4574). Participants who shopped frequently at supermarkets, specialty stores, and farmer’s markets consumed more fruits and vegetables than those who did not (p<0.01). BMI and waist circumference were significantly lower among those who shopped at specialty stores and farmer’s markets (p<0.01). Frequently shopping at convenience stores was associated with poorer dietary quality and lower fruit and vegetable intake (p<0.05). One of the main limitations of the study was that there could be misclassification of obesity status and waist circumference due using self-reported measurements.55

Overall, prior research has found that access and usability of stores with high availability of healthy foods is associated with better diet and self-reported BMI.

## PHRESH Study

This study uses data collected from the Pittsburgh Hill/Homewood Research on Eating, Shopping and Health (PHRESH) study which has a quasi-experimental longitudinal design analyzes the effects of introducing a full-service supermarket into a predominantly Black, low-income neighborhood in Pittsburgh, PA. Compared to those in the control neighborhood, residents in the intervention neighborhood had fewer new diagnoses of high cholesterol (p=0.01) and experienced a much larger decline in food insecurity (p<0.01).56 The prevalence of diabetes increased less in the intervention than the comparison neighborhood (-3.6%, p=0.10).56 Overall dietary quality declined significantly more in the intervention neighborhood.57 There were no significant differences in changes for BMI, fruit and vegetable intake, and perceived access to healthy foods between the intervention and comparison neighborhood.57

While much of the PHRESH research revolves around understanding the effects of different types of stores on diet and health, no research has specifically focused on cardiometabolic outcomes which are directly related to heart related disease status. 56–59 Additionally, PHRESH research has primarily focused on accessibility to healthy fruits and vegetables and not necessarily usability of food stores which provide high access and low access to healthy foods.57,59,60 However, one study found that more frequent shopping at convenience and neighborhood stores is associated with a greater dietary intake of sugar sweetened beverages, added sugars, and discretionary fats.58

## Gaps in Knowledge

As shown, current research is limited in two main ways. First, research has focused on understanding how shopping at specific stores affects healthy food accessibility, diet, and self-reported health measures, but does not evaluate measured cardiometabolic outcomes. Secondly, prior research has primarily focused on understanding geographic accessibility to stores and its effects on diet and self-reported health measures and does not focus as much on the usability of specific store types. Additionally, a large focus of food environment research has been placed on solely supermarkets and convenience stores. The current study is the first, to our knowledge, to assess the association between usability of food stores and cardiometabolic outcomes.

## Public Health Significance

Heart disease is the leading cause of the death in the United States, and disproportionately affects low-income Black populations. As diet is strongly correlated to cardiometabolic health, a great amount of research has studied the effects of the food environment on diet. The current study has important public health significance, as it will help inform food environment interventions aimed at primarily low-income Black populations, specifically trying to understand what types of stores interventions would should be aimed at to fully benefit the cardiometabolic health of this population. It will also identify areas of future food environment research that may be important in improving cardiometabolic outcomes within this population.

# Objective

The objectives of this study are to understand how the food environment (availability, accessibility, and affordability) is associated with cardiometabolic health outcomes in predominately low-income Black residents in neighborhoods that have limited food access and to explore the type of store that may be best suited towards this population to facilitate good health. Further, this study will attempt to understand the association of shopping at specific store types on cardiometabolic health outcomes. We hypothesize that participants with increased access to fruits and vegetables and participants who do their primary food shopping at a full-service grocery stores will have better cardiometabolic and self-rated health.

# Methods

## Study Population

This study uses data collected in 2018 from the Pittsburgh Hill/Homewood Research on Neighborhoods and Health (PHRESH) study, which was designed as a natural experiment to examine the effect of introducing neighborhood investments (supermarket, greenspace, housing) into a predominantly Black, low-income neighborhood in Pittsburgh, PA, compared to a demographically matched comparison neighborhood.

The intervention neighborhood (Hill District) is approximately 3.55km2 and has approximately 10,000 residents. The comparison/control neighborhood (Homewood) is approximately 3.56km2 and has approximately 8,000 residents. In both neighborhoods, 95% of residents were African American and the average self-reported income was less than $15,000 per year. Prior to the introduction of the supermarket in October 2013 into the intervention neighborhood, the closest supermarket was on average at least 1.45 miles away for residents of both neighborhoods.

Data for the PHRESH project was collected at baseline in 2011 and post-interventions in 2014, 2016, and 2018. The original cohort of residents (N=1372) was enrolled as a stratified random sample of household primary food shoppers who were at least 18 years old in the two neighborhoods in 2011. The sampling frame consisted of all occupied residential addresses in both neighborhoods. This address information was obtained from the Pittsburgh Neighborhood Community Information System and Allegheny County Office of Property Investment data. In the intervention neighborhood, the household samples were stratified by distance from the future full-service grocery store site, in which those closer to this site were oversampled. Not stratification was used for the control neighborhood.

At all survey time-points, participants in both neighborhoods were visited by trained community data collectors, who primarily resided in either the intervention or comparison neighborhood, for survey administration. Further detailed methods of the PHRESH study can be found in a prior publication detailing study design, methodology, and primary findings.61

## Household Interviews

For these analyses, community data collectors administered a 90-minute interview within a participant’s home or in a selected community setting between May and November of 2018. Interviews collected information on participants’ sociodemographic characteristics, health habits, and neighborhood perceptions.

In addition to completing a household interview, participants’ height, weight and blood pressure were measured, and participants were invited to provide a blood sample. If the participant consented to the blood draw, a trained study phlebotomist collected 10ml of blood drawn from the antecubital vein while the participant was seated. Due to feasibility concerns, participants were not required to fast prior to the blood draw. Assays were sent to the University of Pittsburgh Heinz Nutrition Laboratory at the Graduate School of Public Health and the University of Pittsburgh Medical Center (UPMC) Presbyterian hospital. Feedback on assayed blood measures and anthropometric measures were provided to the participant. All study protocols were approved by the RAND Corporation’s Institutional Review Board and the University of Pittsburgh’s Institutional Review Board.

Sociodemographics collected included neighborhood of residence (Hill/Homewood/Other), years lived in neighborhood, sex (male/female), marital status/living with partner (yes/no), highest education level (less than high school, high school, some college/tech, college/grad degree), and age. Missing data were imputed for marital status/living with partner, years lived in neighborhood, and income using multiple imputation to reduce measurement error and sampling bias.

## Independent Variables

### Perceptions of Access to Fruit and Vegetables

Participants were asked how much they agree with four different statements about fruit and vegetables availability in their neighborhood on a scale of 1-5 (1=strongly disagree and 5=strongly agree): *It is easy to buy fruits and vegetables in my neighborhood*; *there is a large selection of fruits and vegetables in my neighborhood*; *the fruits and vegetables in my neighborhood are of high quality*; and *the price of fruits and vegetables in my neighborhood is acceptable to me*. Each variable was dichotomized into agree (strongly agree and agree) and disagree (strongly disagree, disagree, and neither agree nor disagree). All four statements were analyzed as individual items.

### Store Type

Participants rated how frequently they went to eleven different types of food retail venues when they wanted to buy food. The response scale consisted of a four-point scale ranging from never to often. Examples of store types, including Aldi, Walmart, and Giant Eagle, were provided for clarification of which stores belonged in which category. The scale was collapsed into a 3-point scale with answers “never(0),” “occasionally/sometimes(1)” and “often(2),” with “occasionally” and “sometimes” combined into a single category as they convey similar meaning.

We then classified food retail venues into two categories, low-access and high-access to healthy foods, based upon prior PHRESH store audit data which detailed the average number of healthy and unhealthy foods available in different store types.58,50 Stores with low access to healthy foods included convenience stores, neighborhood stores, dollar stores, and drug stores. Stores with high access to healthy foods were discount grocery stores, supercenters, wholesale clubs, full-service supermarket, specialty grocery stores, meat or seafood markets, and fruit and vegetable stores/farm stands.

A count variable was created to represent frequency of shopping at low and high healthy food access stores. Two new summary variables were created for shopping frequency at low or high access stores by summing all responses to shopping frequency at low or high access to healthy food stores. Both of these count variables were then categorized into “rarely”, “sometimes”, and “often” to represent frequency of shopping at low access and high access to healthy food stores.

### Major Food Shopping

Participants provided the name and address of the main store where they did their major food shopping. Seven categories emerged from these responses: Discount grocery store (e.g., Aldi’s; Bottom Dollar), supercenter (e.g., Target; Walmart), wholesale club (e.g., Sam’s Club, Costco), specialty grocery store (e.g. Whole Foods; Trader Joes), full-service supermarket (e.g. Giant Eagle; Shop N Save), meat or seafood market, and fruit and vegetable store (e.g. farmer’s market). Due to similarities in some of the categories, store type was condensed into 4 categories: Discount grocery store, supercenter or wholesale club, full-service supermarkets, and specialty store (specialty grocery store, meat or seafood market, and fruit and vegetable store). Additionally, participants provided the number of times they visited this primary store for major food shopping in the past month. This variable was categorized as: 0-1 times, 2-3 times, and 4 or more times. Lastly, participants chose the main reason they did their major food shopping at their primary store: 1) quality of food, 2) price, 3) convenience of location, and 4) Choice of items, customer service, cleanliness, or fuel perks.

## Outcome Variables

### Self-rated Health

During the interview, participants rated their health on the BRFSS (Behavioral Risk Factor Surveillance System) 5-point scale from excellent to poor.62 This scale has been proven to be valid to measure health status in different ethnic groups.63 This variable was dichotomized into fair/poor health and good health (good, very good, and excellent).

### Body Mass Index

BMI was calculated from participant’s measured height and weight. Height was measured with no shoes on to the nearest eighth-inch using a carpenter’s square and an eight-foot folding ruler. Weight was measured to the nearest tenth-pound using a Seca Robusta 813 digital scale. BMI was categorized into normal weight (<25 kg/m2) and overweight/obese (>=25 kg/m2).

### Blood Pressure

Blood pressure was measured using a Micro Life automated blood pressure monitor after the participant was seated for five minutes. Three measurements were taken, and the average of the last two measurements were used to calculate mean systolic and diastolic blood pressure. High blood pressure was defined as SBP >= 140mmHG or DBP >= 90 mmHg or currently taking high blood pressure medication.

### Cardiometabolic Profile

American Diabetes Association criteria was used to define high blood sugar, high cholesterol, and low HDL.64 A participant was classified as having high blood sugar if their measured HbA1c was greater than or equal to 6.5% or were taking diabetes medication. High cholesterol was defined as total cholesterol greater than or equal to 200 mg/dL or taking cholesterol medications. Lastly, low HDL was defined as less than or equal to 40mg/dL. Medications were assessed by the data collector asking the participant to provide a list of current medications.

## Statistical Analyses

Overall, the PHRESH study collected household interview data on 701 participants. However, only 459 participants completed the additional blood draw and therefore were included in the study sample for this analysis.

Univariate descriptive statistics were calculated to characterize participants’ sociodemographics, food shopping perceptions and habits, and health outcomes. To understand if participants included in the blood sample were representative of the entire PHRESH study population, those who did or did not provide a blood draw sample were compared across study variables, with significant differences assessed using chi-squared tests.

Unadjusted and adjusted logistic regression models were used to assess the associations between 1) perceived fruit and vegetable availability, quality, and price, 2) frequency of shopping at low and high healthy food access stores, and 3) primary food shopping store type and reason for shopping there, and cardiometabolic and self-rated health outcomes. Adjusted models included an indicator of neighborhood to account for the natural experiment design of the PHRESH study. Adjusted models also included the additional individual-level covariates of age, race, income, education, marital status, and years lived in neighborhood. The basic assumptions of logistic regression were confirmed: binary dependent variable, independent observations, little collinearity among independent variables, and linearity of independent variables. All analyses were performed in STATA 16.

# Results

## Characteristics of Study Participants

Demographic characteristics of the study participants are shown in Table 1. The average age of participants was 60.7 years (SD=13.9), and 81.7% of participants were female, 14.6% of participants were either married or living with their partner, 88.4% had a high school education or higher, and median income per household member was $12,500 (IQR: $6250-$17500). Participants had lived an average of 32 years in their neighborhood.

Demographics and independent variables did not significantly differ between those in the PHRESH study who gave blood (n=459) and were included in this analysis and those who did not give blood (n=242) and were excluded from the analysis. High blood pressure and overweight/obese status were significantly more prevalent in the blood draw sample versus the sample without a blood draw (78.8% vs. 67.9% and 80.92% vs. 71.8%, respectively).

The majority of participants indicated that their primary food shopping store was a full-service supermarket (68%) and chose their primary food shopping store based on the quality of food (31.4%) or the convenience of its location (27%). Mostly commonly, participants visited their primary food shopping store 2 to 3 times a month (49%).

## Associations of Independent Variable and Outcomes

### Accessibility and Affordability of Fruits and Vegetables

After covariate adjustment, greater perceived accessibility of purchasing fruits and vegetables in one’s neighborhood was associated with 53% lower odds of high blood pressure (OR=0.47, 95% CI: 0.28, 0.79) and 41% lower odds of poor/fair self-rated health (OR=0.59, 95% CI=0.39, 0.90) (Table 2). Additionally, perceived affordability of fruits and vegetables in one’s neighborhood was associated with 41% lower odds of high blood pressure (OR=0.59, 95% CI=0.36, 0.96). Perceived affordability of fruits and vegetables was associated with lower odds of poor/fair self-rated health (OR=0.64, 95% CI: 0.42, 0.97). Lastly increased perceptions of high quality of fruits and vegetables being available in one’s neighborhood was associated with lower odds of poor/fair self-rated health (OR=0.62, 95%CI: 0.41, 0.94) (Table 2).

### Primary Shopping

Doing one’s primary food shopping at a discount grocery store versus a full-service grocery store was associated with 49% lower odds of being overweight (OR=0.51, CI: 0.26, 0.99) (Table 3). Higher monthly frequency of visits to a primary food store was associated with lower odds of low HDL (OR=0.74, 95%CI: 0.55, 0.98). Choosing a primary food store based on price rather than quality of food was associated with a 2-fold increase in the odds of high total cholesterol (OR=2.02, 95% CI: 1.19, 3.45) (Table 3).

### Shopping Frequency at Stores with Low/High Access to Healthy Foods

Shopping often vs. rarely at stores with low access to healthy foods was associated with a 3.5-fold increase in odds of high cholesterol (OR=3.52, 95%CI: 1.09, 11.40) (Table 4). Shopping often vs. rarely at stores with high access to healthy foods was associated with 42% lower odds of poor/fair self-rated health (OR=0.58, 95%CI: 0.15, 0.85) (Table 4). Also, shopping sometimes vs. rarely at stores with high access to healthy foods was associated with 42% lower odds of poor/fair self-rated health (OR: 0.58, 95%CI: 0.36, 0.92).

# Discussion

The findings from this study suggest that higher perceived access to fruits and vegetables in one’s neighborhood, choice of primary food shopping store, and frequency of shopping at stores with high and low access to healthy foods are important correlates of cardiometabolic health. In addition, we found evidence that greater accessibility and affordability of healthy foods are important predictors of both better cardiometabolic and self-rated health for low-income Black populations. This analysis adds to current literature suggesting that improvements in the neighborhood food environment can positively influence dietary behaviors and cardiometabolic health.32,33 Our results are supported by a strong sampling frame, with participants who were randomly selected from our study neighborhoods and clinically measured outcomes.

We found that higher perceptions of fruit and vegetable accessibility and affordability in one’s neighborhood were associated with a lower likelihood of high blood pressure and poor/fair self-rated health (Table 2). Specifically, in terms of accessibility, the ease of buying fruits and vegetables was associated with good self-rated health and 53% lower odds of high blood pressure, however having a large selection of fruits and vegetables did not show any significant association with self-rated health or cardiometabolic outcomes. These findings suggest that a potential avenue of intervention at the food environment level for low-income Black populations should focus on improving accessibility and affordability of fruits and vegetables.

Prior studies, including work within this sample, which evaluated the impact of placing supermarkets in food deserts, did not find a significant improvement in fruit and vegetable intake as a result of the new supermarket.49,57 However, one previous study in both low and high SES primary food shoppers identified that price reductions on fruits and vegetables in supermarkets were significantly associated with an increase in fruit and vegetable consumption.65 Results from the literature suggest that both supermarket accessibility and affordability interventions might help consumers bridge the gap between improvements in fruit and vegetable accessibility and action leading to behavior change.49 This supports our study findings as it indicates that both increased accessibility and affordability of fruit and vegetables may have a positive effect on decreasing the prevalence of cardiometabolic risk factors in this population.

Contrary to our hypothesis and expectations given prior work, doing one’s primary food shopping at a discount grocery store versus a full-service grocery store was associated with a lower likelihood of being overweight. This could be due to the fact that while discount grocery stores may not offer fruits and vegetables at the large selection of supermarkets, they usually offer what’s available at lower prices, thus improving their affordability.58 Previous quasi-experimental longitudinal studies, including work from the PHRESH study, found no improvement in BMI or fruit and vegetable intake after opening a supermarket in a low-income primarily Black community may partially explain the null findings between primary food shopping at full-service grocery store and cardiometabolic outcomes .49,61 Additionally, most people within this population chose to do their primary food shopping at a store due to prices rather than quality of food which sheds further light on the possible importance of discount grocery stores.34

Discount grocery stores, which began gaining popularity in 2008 after the recession, focus on low cost operations and merchandising by focusing on competitive prices within a small store format and own-brand products.66–68 Aldi, the most prevalent discount grocery store in the United States and in close proximity to the two study neighborhoods, has a 13 dollar lower price per basket for 40 common foods compared to Wal-Mart.68,69 Beginning in 2017, Aldi placed a large emphasis in improving the availability and quality of organic meats and foods, high-end foods (quinoa, artisan cheeses, smoked salmon), fresh fruits and vegetables, and vegan and gluten-free options.68,70 Due to the only recent widespread use of discount grocery stores, there is limited literature understanding the effects that shopping at a discount grocery store has on diet and overall health. Our study supports and adds to this small body of literature which has suggested that discount grocery stores may be an important correlate of good dietary and cardiometabolic health in low-income populations due to their offering of low-priced healthy foods.34,71

Results from this study support and expand on the current literature by showing that shopping at small stores with low access to health foods is associated with negative cardiometabolic outcomes.41,58 Interestingly, shopping sometimes and often at stores with high access to healthy foods was only associated with better self-rated health and not with any cardiometabolic outcomes. This could be that frequently shopping at stores with high access to healthy foods does not necessarily mean that people frequently purchase and consume these healthy foods. In stores with high access to healthy foods, unhealthy foods are still readily available and prominently displayed.58 Therefore, these findings support prior research pushing for interventions that curb unhealthy food purchases at stores with high access to healthy foods in order to produce meaningful improvements in diet and cardiometabolic outcomes.42 Further research should be aimed towards understanding how direct food choices made at stores impact cardiometabolic health.

## Strengths and Limitations

The primary strength of this work is that it is one of the first studies, to our knowledge, to examine the association between the food environment on measured cardiometabolic outcomes. Most previous studies look at dietary, self-reported BMI, and self-reported cardiometabolic outcomes while we report on measured cardiometabolic outcomes including blood pressure, blood sugar, cholesterol, and BMI. Additionally, this study not only examined the geographic food environment, but it specifically related individual usage of different food stores to measured cardiometabolic outcomes.

One of the main limitations of the study is that it is cross-sectional, so no causal inferences can be made. Secondly, we had limited generalizability as this was a primarily low-income, Black, and female population; however, the study design and population allowed us to determine specific areas of future research and intervention that can be tailored to help improve health in this at-risk population. Third, there is some self-selection in the study population, as those who participated in the blood draw were more likely to have high blood pressure and more likely to be overweight compared to those that did not participate in the blood draw.

## Conclusion

In conclusion, this study shows the need for interventions to be focused improving both the accessibility and affordability of fruits and vegetables within primarily low-income Black populations to have a positive effect on self-rated and cardiometabolic health. Interventions centered around discount grocery stores may be particularly impactful specifically due to having high access to affordable healthy foods. However, further research should be done to investigate the relationship between shopping at discount grocery stores and cardiometabolic health. Additionally, interventions should focus on curbing unhealthy food choices and purchases in supermarkets and discount grocery stores in order to better cardiometabolic health. This study highlights the public health significance of the food environment and its effects on cardiometabolic and self-rated health outcomes.

Appendix Tables

Table 1. Demographic characteristics of participants in the PHRESH study who gave blood samples versus those who did not give blood samples, 2018 (N=701)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Blood Draw Participants (N=459)** | **Non Blood Draw Participants**  **(N=242)** | **p-value** |
|  | **N (%)** | **N (%)** |  |
| **Neighborhood** |  |  |  |
| Hill District | 305 (66.5) | 142 (58.7) | 0.12 |
| Homewood | 108 (23.5) | 72 (29.8) |  |
| Other | 46 (10.0) | 28 (11.6) |  |
| **Years lived in neighborhood (mean, SD)** | 32.4 (22.9) | 31.43 (23.5) | 0.59 |
| **Sex** |  |  |  |
| Female | 375 (81.7) | 188 (77.7) | 0.20 |
| Male | 84 (18.3) | 54 (22.3) |  |
| **Marital Status a** |  |  |  |
| Not married | 392 (85.4) | 209 (86.4) | 0.73 |
| Married or living with partner | 67 (14.6) | 33 (13.6) |  |
| **Highest Education Level** |  |  |  |
| Less than High School | 53 (11.6) | 23 (9.5) | 0.81 |
| High School | 176 (38.3) | 95 (39.3) |  |
| Some college/tech | 173 (37.7) | 90 (37.2) |  |
| College/Grad Degree | 57 (12.4) | 34 (14.1) |  |
| **Age (mean, SD)** | 60.7 (13.9) | 59.6 (16.0) | 0.40 |
| **Income per household member**  **(thousands) a (median, IQR)** | 12.5 (6.3-17.5) | 11.7 (5.8-17.5) | 0.83 |
| **BMI** |  |  |  |
| Normal Weight | 87 (19.1) | 62 (28.2) | **0.007** |
| Overweight or Obese | 369 (80.9) | 158 (71.8) |  |
| **High Blood Pressure** |  |  |  |
| No | 95 (21.2) | 72 (32.1) | **0.002** |
| Yes | 354 (78.8) | 152 (67.9) |  |

a Variable was imputed to account for missing values

Table 2. Adjusted models for association between fruit and vegetable perceptions and cardiometabolic outcomes for PHRESH study blood draw participants, 2018 (N=459)a,b

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ***High Blood Pressurec***  ***OR (95%CI)*** | ***High Blood Sugard***  ***OR (95%CI)*** | ***High Cholesterole***  ***OR (95%CI)*** | ***Low HDLf***  ***OR (95%CI)*** | ***Overweightg***  ***OR (95%CI)*** | ***Poor/Fair Healthh***  ***OR (95%CI)*** |
| **Easy to buy F and V** | **0.47 (0.28, 0.79)\*\*** | 1.08 (0.71, 1.64) | 1.33 (0.89, 1.98) | 1.23 (0.80, 1.87) | 1.05 (0.63, 1.74) | **0.59 (0.39, 0.90) \*** |
| **Large selection F and V** | 0.66 (0.41, 1.06) | 0.96 (0.64, 1.44) | 1.27 (0.86, 1.86) | 1.13 (0.75, 1.70) | 1.05 (0.64, 1.71) | 0.67 (0.45, 1.01) |
| **High Quality F and V** | 0.86 (0.53, 1.39) | 1.02 (0.69, 1.53) | 1.20 (0.81, 1.77) | 1.06 (0.70, 1.60) | 1.25 (0.76, 2.07) | **0.62 (0.41, 0.94) \*** |
| **Good Price F and V** | **0.59 (0.36, 0.96) \*** | 1.05 (0.70, 1.60) | 1.24 (0.83, 1.84) | 0.92 (0.60, 1.40) | 0.89 (0.54, 1.47) | **0.64 (0.42, 0.97) \*** |

Note: All models are derived from logistic regression; OR = Odd’s Ratio; 95%CI = 95% Confidence interval; F and V = Fruit and Vegetables

*a* Adjusted for age, sex, adjusted income, marital status, education, neighborhood, years lived in neighborhood

*b* Survey question had answer options of strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. Each fruit and vegetable perception variable analyzed within the model as two categories agree (containing answer options agree and strongly agree) or disagree (containing answer options strongly disagree, disagree, and neither agree nor disagree).

c High blood pressure defined as SBP >=140 mmHg or DBP >= 90mmHG, or taking blood pressure medication

d High blood sugar defined as HgBA1c >= 6.5% or on diabetes medication

e High cholesterol defined as total cholesterol >= 200 mg/dL or on cholesterol medication

f Low HDL defined as HDL <=40 mg/dL

g Overweight defined as BMI>=25.0 kg/m2

h Original survey question had answer options of excellent, very good, good, fair, and poor. For this analysis, health was dichotomized as poor (containing answer options fair and poor) and good (containing answer options good, very good, and excellent).

\*p<=0.05

\*\*p<=0.01

Table 3. Adjusted models for relationship between primary food shopping store qualities and cardiometabolic outcomes for PHRESH study blood draw participants, 2018 (N=459)a

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ***High Blood Pressurec***  ***OR (95%CI)*** | ***High Blood Sugard***  ***OR (95%CI)*** | ***High Cholesterole***  ***OR (95%CI)*** | ***Low HDLf***  ***OR (95%CI)*** | ***Overweightg***  ***OR (95%CI)*** | ***Poor/Fair Healthh***  ***OR (95%CI)*** |
| **Primary food shopping store** |  |  |  |  |  |  |
| Discount grocery store v. FSG | 0.60 (0.32, 1.15) | 1.49 (0.83, 2.68) | 1.54 (0.87, 2.72) | 1.11 (0.61, 2.02) | **0.51 (0.26, 0.99)\*** | 0.67 (0.36, 1.22) |
| Supercenter/Wholesale club v. FSG | 1.07 (0.51, 2.22) | 0.97 (0.52, 1.84) | 1.21 (0.66, 2.21) | 1.19 (0.65, 2.21) | 0.67 (0.31, 1.44) | 1.08 (0.59, 1.97) |
| Specialty Storeb v. FSG | 0.84 (0.28, 2.56) | 0.51 (0.16, 1.59) | 1.70 (0.67, 4.35) | 1.23 (0.46, 3.26) | 1.12 (0.31, 4.09) | 0.52 (0.16, 1.64) |
| **Times visited Primary food store past month** | 1.15 (0.83, 1.61) | 1.2 (0.92, 1.62) | 1.08 (0.83, 1.41) | **0.74 (0.55, 0.98)\*** | 0.97 (0.69, 1.36) | 0.92 (0.69, 1.22 |
| **Reason chose to do food shopping at primary store** |  |  |  |  |  |  |
| price v. quality of food | 0.888 (0.47, 1.68) | 1.22 (0.70, 2.11) | **2.02 (1.19, 3.45)\*** | 1.04 (0.60, 1.81) | 0.89 (0.45, 1.76) | 0.96 (0.55, 1.66) |
| convenience of location v. quality of food | 0.96 (0.51, 1.80) | 0.97 (0.57, 1.64) | 1.14 (0.69, 1.89) | 1.29 (0.77, 2.17) | 0.74 (0.40, 1.37) | 0.78 (0.46, 1.30) |
| Otherc v. quality of food | 1.08 (0.53, 2.22) | 0.95 (0.53, 1.72) | 1.11 (0.63, 1.97) | 1.08 (0.60, 1.95) | 1.00 (0.48, 2.10) | 0.93 (0.51, 1.68) |

Note: All models are derived from logistic regression; OR = Odd’s Ratio; 95%CI = 95% Confidence interval, FSG = full-service grocery store

*a* Adjusted for age, sex, adjusted income, marital status, education, neighborhood, years lived in neighborhood

b Specialty store includes specialty grocery store, meat or seafood market, and Fruit and Vegetable store

c Other includes choice of items, customer service, cleanliness, and fuel perks

d High blood pressure defined as SBP >=140 mmHg or DBP >= 90mmHG, or taking blood pressure medication

e High blood sugar defined as HgBA1c >= 6.5% or on diabetes medication

f High cholesterol defined as total cholesterol >= 200 mg/dL or on cholesterol medication

g Low HDL defined as HDL <=40 mg/dL

h Overweight defined as BMI>=25.0 kg/m2

i Original survey question had answer options of excellent, very good, good, fair, and poor. For this analysis, health was dichotomized as poor (containing answer options fair and poor) and good (containing answer options good, very good, and excellent).

\*p<=0.05

Table 4. Adjusted models for relationship between frequency of shopping at stores with low or high access to healthy foods and cardiometabolic outcomes, for PHRESH study blood draw participants, 2018 (N=459)a

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ***High Blood Pressure ORd (95% CI)*** | ***High Blood Sugare***  ***OR (95%CI)*** | ***High Cholesterolf***  ***OR (95%CI)*** | ***Low HDLg***  ***OR (95%CI)*** | ***Overweighth***  ***OR (95%CI)*** | ***Poor/Fair Healthi***  ***OR (95%CI)*** |
| **Frequency shopping at stores with low access to healthy foodb** | |  |  |  |  |  |
| Sometimes v. rarely | 1.48 (0.87, 2.58) | 0.80 (0.51, 1.27) | 1.12 (0.72, 1.73) | 0.74 (0.46, 1.17) | 0.95 (0.55, 1.64) | 1.10 (0.70, 1.71) |
| Often v. rarely | 0.57 (0.18, 1.81) | 1.23 (0.35, 4.29) | **3.52 (1.09, 11.40)\*** | 1.62 (0.52, 5.07) | 0.74 (0.18, 3.02) | 0.59 (0.17, 2.08) |
| **Frequency shopping at stores with high access to healthy foodc** | |  |  |  |  |  |
| Sometimes v. rarely | 1.46 (0.82, 2.58) | 0.86 (0.53, 1.39) | 1.06 (0.67, 1.69) | 1.02 (0.62, 1.67) | 0.90 (0.51, 1.59) | **0.58 (0.36, 0.92)\*** |
| Often v. rarely | 0.94 (0.40, 2.23) | 0.90 (0.39, 2.09) | 0.98 (0.45, 2.16) | 1.51 (0.68, 3.34) | 0.90 (0.51, 1.59) | **0.36 (0.15, 0.85)\*** |

Note: All models are derived from logistic regression; OR = Odd’s Ratio; 95%CI = 95% Confidence interval

*a* Adjusted for age, sex, adjusted income, marital status, education, neighborhood, years lived in neighborhood

b Low access stores include convenience stores, drug stores, neighborhood stores, and dollar stores

cHigh access stores include discount grocery stores, supercenters, wholesale clubs, grocery stores, full-service supermarkets, meat or seafood markets, and fruit and vegetable stores or farm stands

d High blood pressure defined as SBP >=140 mmHg or DBP >= 90mmHG, or taking blood pressure medication

e High blood sugar defined as HgBA1c >= 6.5% or on diabetes medication

f High cholesterol defined as total cholesterol >= 200 mg/dL or on cholesterol medication

g Low HDL defined as HDL <=40 mg/dL

h Overweight defined as BMI>=25.0 kg/m2

i Original survey question had answer options of excellent, very good, good, fair, and poor. For this analysis, health was dichotomized as poor (containing answer options fair and poor) and good (containing answer options good, very good, and excellent).

\*p<=0.05

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