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Research Article

Differences in Race, Median Household Income and Food Store Constructs from Large and Small Food Locations: an Urban and Suburban Spatial Analysis of Food Access in a Flint, Michigan

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Abstract

Objective: To spatially examine the relationship between food availability, food price and food quality in a variety of types of food stores along with race and income in city of Flint, Michigan and 2-mile suburban buffer.

Design: Cross-sectional study spatially examining race and median household income and food availability, food price and food quality collected from 273 urban and suburban food stores in summer 2012.

Setting: Census tracts within the city of Flint, Michigan and a two-mile suburban buffer surrounding the city.

Main Outcomes Measure: Availability of 63 food items, food quality of 10 fresh vegetables and 10 fruit and the food price of select items that were examined relative to race and income variables.

Analysis: A spatially explicit regression analysis.

Results: Food availability and quality increased as the percent Black1 in the census tracks decreased. Notably, this differed depending on the size of the store. Food availability increased significantly as the median household income increased. Food quality increased as census tract level median household income increased, but not by much.

Conclusion and Implications: Differences in food availability, price and quality based on race and income can be harmful to the health of marginalized, minority and minoritized resident groups, especially those with low income. These differences can indicate the absence of resources in such communities.

ABBREVIATIONS

MHH$: Median Household Income; USD: United States Dollars

INTRODUCTION

The spatial examination of neighborhood food access -measured by food availability, food price and food quality- is critical for assessing the adequacy of healthy choices and hence good health. Studies show that larger grocery store such as supermarket access is associated with lower mortality, rates of diabetes and diabetes risk [1,2]. Additionally, the quality and price of fresh fruit and vegetables were integral in deciding what and when to purchase, particularly in the context of their children's sake [3]. Race and ethnicity are factors that predict food access. Studies show that predominantly Black census tracts are associated with more corner stores [4] and few supermarkets when compared to non majority- Black areas [4,5]. These Black communities also have poorer quality of fruit and vegetables when compared to racially mixed communities [6]. The disparate availability of healthy food can regrettably be seen across multiple-income populations.

In studies of food access, at least one has included spatial autocorrelation within communities [7] when accessing healthy foods, however not explicitly for the town of Flint, MI [8,9]. The nearby, proximal food environment disproportionately impacts the healthfulness of accessible food, and can subsequently impact one's health. Unfortunately, many marginalized groups more likely have access to only smaller food stores, which typically sell more nutrient-poor foods [10,11], which has implications for the diet and long-term health of these lower-income and minority groups [10-12].

The implications of differential access to a variety of healthy foods and larger food establishments can impact health, particularly rates of obesity [13] and diabetes [2]. Prior work examining food store access (e.g., food availability, food quality and food price) and demographic variables rarely include assessment for spatial autocorrelation of the measures of food store access [8]. Spatial autocorrelation, a measure of similarity or dissimilarity over space in variables such as access to healthy food, can be used to assess the significance of non-randomness in that variable over space. This is important because non-randomness in access to healthy foods can be an indicator of the extent of equity in resource distribution in a community. Potential violations of independence in these measures could bias results and yield false relationships amongst the demographic variables and food availability, quality and price. Spatial autocorrelation of measures of food store access may have a significant impact on food access within a community.

The purpose of this study was to explore constructs of food access alongside demographic measures using spatially explicit modelling. Flint, Michigan is a community with that has not completely resolved the causes of and negative outcomes associated with the 'Water Crisis' beginning in 2014 [14]. This study provides a snapshot in time of differences in food access that can also be seen in conjunction with the presence or absence of other resources. We investigated race, median household income, food availability, food price and food quality in an urban city and a surrounding 2-mile suburban buffer. Our hypotheses were that food availability, quality and price scores would be lower in census tracts with a larger percentage of Blacks and lower median household incomes, and that lower food price scores correspond with higher food prices.

METHODS

Instrument and Procedures

This cross-sectional study was conducted in the city of Flint, Michigan and a 2-mile suburban buffer surrounding the city. Flint has experienced a decrease in population (103,263 to 95,999 from 2012 to 2020) of over 7,000 residents from 2012 to 2020; however, during the same time, median household income increased for Whites and Blacks (Population from 20212 to 2020; Median HH Income based on race 2021 to 2020). Researchers assessed a variety of food in stores from a list provided by the Michigan Department of Agriculture (MDA); with each location verified before assessment. Stores identified from the MDA were mailed letters describing the study in both English and Arabic. The Arabic language was necessary because of the purported size of Arabic speakers that were business owners by according to a key stakeholder and a member of the Arab American Heritage Council. New stores were added when discovered in the field. Stores were grouped based on type. Integral census tract-level demographic variables of race and median household income were analyzed. Assessments were conducted by two trained locally hired residents familiar with the city and two undergraduate university students.

Instruments/Measures

Statistical software R was used to conduct the statistical analyses (R Development Core Team, 2023). Three food access constructs were examined in this study: food availability of commonly consumed foods; food price, especially differences in price of select foods; and food quality by measuring quality of fresh fruit and vegetables. Foods were chosen based on a variety of foods (proteins) commonly consumed by Americans and those reflecting the Dietary Guidelines for Americans [15-17], food in the Dietary Approaches to Stop Hypertension Diet (DASH) [18], and some additional that were important to add based on the community partners' input.

Store-scores were created for each construct, representing the availability, quality, and price of select foods. Race and median household income were obtained from the Census Bureau American Community Survey (ACS) 2009 to 2013, from inhabited census tracts in Flint and the two-mile suburban area. Stores assessed included the variety of stores one can patronize within a community selling a variety of foods: gas stations, gas stations with convenience stores, convenience stores, large grocery stores, small grocery stores. There were 201 stores assessed in Flint and 87 in the suburbs. Percent agreement regarding meeting study criteria ranged from 0.68 to 1.00 for the two pairs of store assessors. All protocols were approved by the Michigan State University Institutional Review Board.

Food constructs

Food availability scores ranged from 0 to 78. Scores represented six food groups based on yes/no availability of 63 items. A higher score indicated more items available: 0 points if nonavailable, 3 points if 1to 2 items were available, 4 points if 3 to 4 were available, 5 points if 5 to 6 were available, 6 points if 7 to 8 were available, 7 points if 9 to 10 were available and 8 points if 11 or more were available. The six food groups included dairy, protein, beverages, fruit, vegetables and grains for the analysis. Food quality included the 10 most consumed fresh fruit and 10 fresh vegetables. They were scored based on acceptability for a total possible 20 points. If more than 50% were 'acceptable' that means the items were in peak condition, top quality, good color, fresh, firm and clean. If less than 50% were in 'unacceptable' condition, they were bruised, old looking, mushy, dry, overripe, had dark sunken spots in irregular patches or cracked or broken surfac displayed signs of shriveling, mold or excessive softening. Points were awarded 1 or 0, respectively.

Food price included dairy, protein, fruit, vegetables, and grains and ranged from 0 to 20 for 10 items; lower price scores corresponded to higher food prices. Selected nutrient dense and energy dense items from the dairy, protein and grain group were compared to the mean value of the same items from the 15 standard stores (i.e. stores used as benchmark stores such as Kroger, Meijer, Aldi's, Wal-Mart, Save-A-Lot and VGs etc.). Items included low-fat and whole milk, lean ground and regular ground beef, whole wheat/whole grain and white bread, brown and white rice and whole grain and white pasta. If the price was lower or the same than the mean value, one point was awarded. If the price was higher than the mean value, zero points were awarded. Five fruit and vegetables were chosen to represent fruits and vegetables consumed by Americans that excluded juice and juice drinks. The five fruits and vegetables were oranges, apples, bananas, grapes, watermelon, white potatoes, tomatoes, onions, head lettuce, and sweet corn. We created a score to represent the price for a half and a whole gallon of milk. They were combined; thus scores were based on the combination of half and gallon of low-fat and whole milk. Ground beef was based on the price per pound. Further description of the components of this study were outlined in a previously published article [19]. The scoring schema is available from the first author by request.

Race and median household income

Race was represented as a continuous variable, percent Black of residents within the census tract. Median household income was also a continuous variable ranging $8,570 to $77,353 from the Census Bureau ACS 2009-2013. For more descriptive statistics, please refer to Table 1.

Statistical Analysis

Results from stores were evaluated for missing data and patterns of missingness prior to statistical analysis. Missing data were addressed by creating codes that accounted for values left blank for each of the variables used in the data analysis. Spatially explicit regression analyses were conducted to evaluate the relationship between food availability, price and quality scores and race and median household income. First, ordinary least squares (OLS) regression [20] was conducted for initial model selection. Akaike information criteria (AIC) were calculated [21,22] to assist in model selection. Lower AIC values indicate lower prediction error and a better model fit [22]. Evaluating error terms for independence over space is particularly important when working with mapped data due to the potential for spatial autocorrelation [23,24]. To test for spatial autocorrelation, Lagrange Multiplier (LM) diagnostic tests were run [25] at a 5% level of significance: LM-error (LM-err) diagnostic tests for autocorrelation of the error terms; LM-lag diagnostic tests for autocorrelation of store scores. If LM-err tests were significant, a spatial error regression model was used to test hypotheses related to race or median household income. If LM-lag tests were significant, a spatial lag model was used for hypothesis testing. If neither test was significant, it was concluded that the OLS model was adequate to test hypotheses related to race or median household income.

Multi-collinearity was addressed by evaluating correlation and variance inflation factors [20]. Since the data in this analysis are multilevel, where stores exist within census tracts, it was necessary to assess intraclass correlation (ICC) before conducting the spatial regression analyses. ICCs were calculated to test for independence of store and census tract level variances for each of the food constructs described above; ICC values range from zero, indicating not correlated, to one indicating complete correlation [22]. All analyses were completed using R 3.2.2 and R Studio open-source software.

Table 1: Descriptive Statistics for Store Scores for Food Availability, Food Price and Food Quality for Race and Median Household Income

Category	Mean	Min	Max	Median
Availability	21.65	0	78	19
Price	0.53	0	14	0
Quality	2.01	0	20	0
% Black	47.3	0.04	97.69	42.61
Median Household Income, USD	29,814	8,570	77,353	27,355
Median Household Income MHH$), Black	24,140	8,570	38,610	24,200
Median Household Income, White	33,520	15,230	77,350	34,330

RESULTS

Of the 288 stores included in the final database, 12 were excluded because they were farmers' markets (n=3) or were miscellaneous stores not fitting store criteria (n=9, e.g., kiosk selling snacks inside an office building). Three additional stores were excluded from the analysis because they were in uninhabited census tracts without race and median household income data. The majority were in Flint (n=190, 70%), which included mostly small stores (n=176, 93%). Of the 83 stores in the Suburban area, most were also small stores (n=70, 84%). (Additional information was reported elsewhere [19].

Summarized in Table 1. The maximum scores possible for each food construct were as follows: availability, 78; quality, 20; and price, 20. The highest total store score belonged to a store in the suburbs, but none of the stores received the full 118 points. Median scores for price and quality are zero (i.e., at least 50% of the scores for these constructs are zero), and mean scores are low, particularly for price, where lower price scores corresponded to higher food prices. Histograms of food availability, food price and food quality are shown in Figure 1 to better describe the distribution of these scores. Descriptive statistics are also shown in Table 1 for the potential predictors of store scores: race (represented by percent Black in the census tract corresponding to each store location) and median household income for the corresponding census tract. Percent Black ranged widely from 0.4% to 97.9% in the study area, with a median value of 42.61%. Median household income by census tract ranged from $8,570 to $77,353 with a median of $27,355. Breaking this down into Black and White incomes, the Black median household income ranged from $8,570 to $38,610 (median $24,200) and the While median household income ranged from $15,230 to $77,350 (median $34,330).

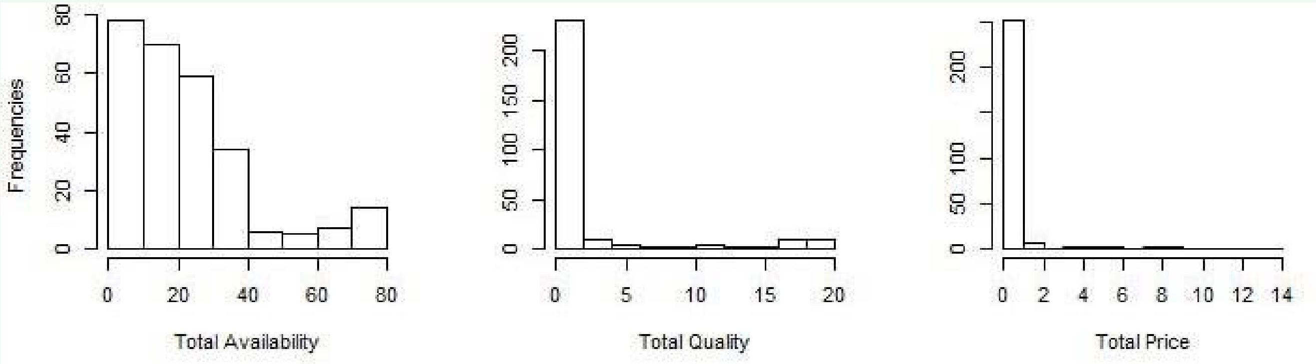

Figure 1 Histograms of food availability, food quality and food price store scores.
Possible points for each construct: Availability scores of 63 items within six food groups = 0 to 78; Price scores of 10 items within five food groups =0 to 20; Quality scores of 20 fresh fruit

REGRESSION ANALYSIS

Impact of Location and Demographics on Food Access

Regression analyses were completed for each construct, with diagnostic testing performed on each "best model" to confirm that underlying assumptions were met before interpreting models. For each construct, hypotheses related to race were tested separately from those related to median household income to avoid multicollinearity since percent Black and median household income were significantly negatively correlated ($r = -0.55$, $p < 0.05$).

Food availability

Best regression models of food availability versus percent Black and median household income, those with lowest AIC and highest adjusted R2 values, are summarized in Table 2. Each model controlled for store size and store location; each a significant predictor of food availability. However, store location was excluded from the best model due to multicollinearity with percent Black and median household income.

Results in Table 2 indicate that as percent Black of the census tract decreased availability of all food groups increased, the percent Black of the census decreased. Significant interaction term indicated that this effect was observed primarily in large stores. Results also indicate that as the median household income increased, food availability of all food groups increased. No significant violations of assumptions were identified in diagnostic tests for each model. Tests of spatial autocorrelation in the error terms for each model were not significant, indicating that spatially explicit regression models were not necessary to test this hypothesis.

Food price

Table 3 summarizes the best regression models for percent Black and median household income relative to food price. As above, each model controlled for store size. Store location, also a significant predictor of food price, was excluded from the best model due to multicollinearity.

Results summarized in Table 3 indicate that food price scores increased (i.e. food prices decreased) as percent Black in census tracts where stores were located decreased. A significant interaction term indicated that smaller stores had lower prices for all food groups. Results also indicate that food price scores increased (prices decreased) as median household income increased. No significant violations of assumptions were identified in diagnostic tests. Tests of spatial autocorrelation in the error terms for each model were not significant, indicating that spatially explicit regression models were not necessary to test this hypothesis.

Food quality

Based on the OLS models summarized in Table 4, food quality of fruits and vegetables increased as percent Black in census tracts decreased. A significant interaction term indicated that this effect differs in large versus small stores. Results also indicate that food quality increased as median household income increased; again, with differing effects in small and large stores. Store size was included in each model as a control variable, although store location was not due to multicollinearity with the percent Black in census tracts and median household income. Accordingly, the best models for food quality included percent Black in census tracts, median household income, store size, and the interaction between these two terms. Tests of spatial autocorrelation in the error terms for each model were not significant, indicating that spatially explicit regression models were not necessary for further hypothesis testing.

DISCUSSION

Spatially, this study captures a moment in time that illustrates differences of the availability, price, and quality of healthy foods that may be an impediment to accessing healthier foods within a

Table 2: Summary of Best Regression Models for Food Availability.

Percent (%) Black							
Predictors	**Est.**	**SE**	**t-stat**	**p-value**	**Adj. R2**	**AIC**	**Comments**
(Intercept)	76.57	4.62	16.58	<2e-16***	0.4487	2255.13	Lowest AIC
% Black	-0.35	0.08	-4.42	143e-05***			and highest
Store size	-59.79	4.90	-12.21	<2e-16***			adjusted $R^{2,}$
% Black X Store size	0.37	0.08	4.32	2.17e-05***			indicating the best model
Median Household Income (MHH$)							
Predictor	**Est.**	**SE**	**t-stat**	**p-value**	**Adj. R^2**	**AIC**	**Comments**
(Intercept)	39.62	9.24	4.29	2.5e-05***	0.4218	2268.15	Lowest AIC
MHH$	6.57e-04	2.75e-04	2.39	0.0175*			and highest
Store size (small)	-20.05	9.72	-2.06	0.0400*			adjusted R^2,
MHH$ X Store size (small)	-7.31e-04	2.91e-04	-2.51	0.0127*			indicating the best model

Signif. codes: 0 '***' 0.001 '**' 0.01 '*'; Est. =estimate, SE=standard error, t-stat=t statistic, Adj. R^2=adjusted R^2, AIC= Akaike information criteria.

Table 3: Summary of Regression Models for Food Price.

Percent (%) Black						
Predictor	**Est.**	**SE**	**t-stat.**	**p-value**	**Adj R^2**	**AIC**
(Intercept)	7.868	0.378	20.84	<2e-16***	0.639	887.8
% Black	-0.066	0.007	-10.1	<2e-16***		
Store size	-7.831	0.4	-19.6	<2e-16***		
% Black X Store size	0.066	0.007	9.54	<2e-16***		
Median Household Income (MHH$)						
Predictor	**Est.**	**SE**	**t-stat.**	**p-value**	**Adj. R^2**	**AIC**
(Intercept)	1.807	0.842	2.15	3.28e-02 *	0.5304	960.28
MHH$	9.7e-05	2.5e-05	3.86	1.41e-04***		
Store size (small)	-1.738	0.886	-1.96	5.074 e-02		
MHH$ X Store size (small)	9.7e-05	02.7e-05	-3.67	2.94e-04***		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*'; Est. =estimate, SE=standard error, t-stat=t statistic, Adj. R^2=adjusted R^2, AIC= Akaike information criteria.

Table 4: Summary of Regression Models for Food Quality.

Predictors	**Est.**	**SE**	**t-stat.**	**p-value**	**Adj.R^2**	**AIC**
(Intercept)	19.60	0.83	23.64	< 2e-16***	**0.7279**	**1317.45**
% Black	-0.11	0.01	-7.59	5.37e-13***		
Store size	-19.22	0.88	-21.86	< 2e-16***		
% Black X Store size	0.11	0.02	7.50	9.44e-13***		
Median Household Income (MHH$)						
Predictors	**Est.**	**SE**	**t-stat.**	**p-value**	**Adj. R^2**	**AIC**
(Intercept)	7.410	1.722	4.303	2.36e-05***	**0.6922**	**1351.04**
MHH$	2.3E-04	5.1E-	4.444	1.29e-05***		
Store size (small)	-6.280	05	-3.466	0.000614***		
MHH$ X Store	-2.3E-	1.812	-4.509	9.71e-06 ***		
size (small)	04	5.4E-				
		05				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*'; Est. =estimate, SE=standard error, t-stat=t statistic, Adj. R^2=adjusted R^2, AIC= Akaike information criteria.

community experiencing a variety of diminished resources. The major finding of this study is that if you shop locally in census tracts with a greater percentage of Blacks, there is less healthy food available, consistent with findings from previous research [26,8]. Further, there is less food available in predominantly Blacks neighborhoods, particularly in larger stores. There was a similar decline in Black residents as food quality increased, which has also been shown in other studies [27,26]. Not surprisingly, the quality difference was more pronounced in larger stores than smaller stores: which indicates a greater variety of perishable items available at larger grocery stores.

Measuring spatial autocorrelation is an integral step when examining foods available from stores in a community. Violation of the independence of variables, in this case the variety of nearby stores assessed in this study, can give erroneous results for the food constructs of food availability, food price, and food quality measured within these stores. As a reminder of Tobler's first law of geography, "everything is related to everything else, but near things are more related than distant things."[24]. Our diagnostic test showed no spatial autocorrelation of food stores, which is a necessary step when conducting statistical analysis with variables in space and time.

Based on our review of the literature, there are few studies that examined spatial autocorrelation alongside food store access. Therefore, we assumed they also did not analyze spatial autocorrelation [7,28]. Zenk and colleagues found that the poorest neighborhoods that were predominantly Black were 1.1 miles farther away from the nearest supermarket than Whites in similarly poor neighborhoods [7]. Another study found that the closest supermarket was more than 3.5 miles away from a quarter of residents in census block groups and over 75% were without a large grocery store within 1 mile of their homes [28]. The last study found and accounted for spatial autocorrelation, and both measured alternate forms of food store access compared to our study.

Income is an important predictor of the availability of healthy foods. When income and race were considered in a study, lower-income communities and predominantly Black communities had significantly fewer healthy foods when compared to higher-income and predominantly White communities [29]. Similarly, healthy foods were more available in high-income areas as demonstrated in Metropolitan Atlanta [30]. A more recent study conducted in Flint found that neighborhoods with a greater number of African Americans had a significantly lower total food score, representing four food categories [28]. In addition to other research conducted in Flint during and after discovering the contamination of lead in the drinking water, this study provides an assessment of the food environment in the city for those of lower income and minorities, specifically Blacks over time.

A major strength of this study was the large number of foods included in the assessment, in addition to the multiple food constructs. Separately, each construct would elucidate an important facet of the food environment but would have been incomplete. Furthermore, GIS (geographic information system) was used to specifically measure each type of food store, which is powerful in examining potential spatial patterns [31]. This study employed spatial autocorrelation; as food store locations are georeferenced data. Accounting for spatial autocorrelation strengthened the statistical analysis by not violating randomness assumptions and the potential correlations with nearby stores across a spatial area, in this case, food stores within census tracts.

This study has several limitations; first the seasonality of the price and availability of fresh fruit and vegetables. Seasonal differences of fruit and vegetables can vary by season [32], and our study may have found different prices and availability of fresh fruit and vegetables if conducted in a different season specifically winter. Second, this study does not measure cleanliness, which was mentioned as a barrier to accessing healthy food by older Black women in Flint [33] and in two predominantly Black urban food environments [34,35]. Finally, this study examined food availability, quality and price within census tracts and the percentage of Blacks and median household income. Census blocks and block groups have fewer residents than census tracts. They are a more granular spatial resolution that was not considered in this study.

CONCLUSION

Proximal access of healthy food is an important resource in one's immediate community. A lack of access to healthy food is an indicator of barriers to access, and the variance by neighborhood is a health inequity. If a household is food insecure, is lesser-abled, depends on insufficient transportation/public transportation, or is older, ability to acquire healthy foods is limited. It is not hyperbole to say that these differences are one of the many issues that play a role in racial and economic health disparities. Communities without larger supermarkets but have more convenience stores also lack the adjacent businesses that may come with larger supermarkets, such as banking and medical clinics [36]. Future work should include analyses like spatial autocorrelations to better identify how food stores help create healthier environments overall.

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