

Comparing Food Desert and Non-Food Desert Residents by Key Socio-Demographic Variables,
Distance to supermarkets, Supermarket Type by Price, Diet Quality and Obesity
in King County, Washington

Lola Stronach

A thesis
submitted in partial fulfillment of the
requirements for the degree of

Master of Public Health

University of Washington
2012

Committee:
Adam Drewnowski, PhD
Anju Aggarwal, PhD

Program Authorized to Offer Degree:
Nutritional Sciences

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INTRODUCTION

Literature Review

One-third of American adults are currently obese (Fleagal et al, 2010). The causes of obesity are multi-factorial; however, decreased access to healthy and affordable foods have emerged as a concerning problem (Morland et al, 2006; Powell et al, 2007). Areas where access to healthy and affordable foods is limited are known as food deserts. Since the term was coined in the early 1990s by a resident in Scotland, the definition of a food desert has evolved and become increasingly more quantified (Beaumont et al, 1995). It is currently defined by the United States Department of Agriculture (USDA) using distance and income as the main criteria and census tracts as the geographic unit. The distance criterion of a food desert is defined as a census tract of at least 500 people where at least 33% reside more than one mile from a supermarket or large grocery store (Ver Ploeg et al, 2009). The income criteria states that the census tract must also have a poverty rate of 20% or higher or a median family income at or below 80% of the area's median family income (Ver Ploeg et al, 2009). A new web-based tool launched in 2011 called the USDA Food Desert Locator was recently developed to identify food desert census tracts across the U.S. using this definition (Ver Ploeg and Breneman, 2011). In fact, The Food Desert Locator has identified approximately 10% of the 65,000+ census tracts as a food desert (Ver Ploeg and Breneman, 2011).

Food desert research has also focused on who resides in identified food deserts. Current research indicates that low-income individuals are more likely to face issues of food access (Ver Ploeg et al, 2009). These same individuals also tend to have lower academic achievement than those who are more food secure. Individuals who are both low-income and have low academic achievement are classified as being of low socio-economic status (SES) (American Psychological Association (APA), 2007). Ethnic minorities are overrepresented in low SES groups (APA, 2007). Thus, residents of food deserts are more likely to belong to an ethnic minority group and have a low SES, compared to residents who do not live in food deserts (Moore and Diez-Roux, 2006; Zenk et al, 2006). Socio-economic status is a known moderator of food accessibility, diet quality and health outcomes (Macintyre, 2007; Chung and Myers,

1999; Adler and Newman, 2002). Current research linking SES and food deserts suggests that residents of low-income neighborhoods often face food access limitations due to the increased distance, higher prices, and lower food quality and variety offered by their local supermarkets (Ver Ploeg et al, 2009; Chung and Myers, 1999; Adler and Newman, 2002; Walker et al, 2010).

Obesity has also been linked to low SES, poor food accessibility, and low diet quality (Morland et al, 2002; Morland et al, 2006; Walker et al, 2010). Food accessibility is limited due to increased supermarket distance and decreased availability of healthy foods, as well as the relative lower cost of energy-dense foods that ultimately result in poor diet quality (Ver Ploeg et al, 2009; Beaulac et al, 2009; IOM and NRC, 2009; Macintyre, 2007; Walker et al, 2010; Frenk, 2011). Studies examining the association between food deserts and obesity are surprisingly limited (Walker et al, 2010). One such study identified supermarkets, grocery stores, and convenience stores in an analysis of obesity and found that African American residents of food deserts were more likely to be obese than their Caucasian counterparts who also lived in food deserts (Morland et al, 2002; Morland et al, 2006).

The overall goal of this study is to describe and compare the SES of participants enrolled in the Seattle Obesity Study (SOS), a large county based study of food cost, access and quality. This study will also analyze the effects of residing in a food desert on measures of diet quality and obesity measures such as body mass index (BMI) among SOS participants.

Specific Aims

The specific aims of this study are described next.

Aim 1: To describe and compare food-desert and non-food desert residents by key socio-demographic variables, physical proximity to supermarkets and supermarket type by price.

Hypotheses:

Food-desert residents tend to be from lower income and education, groups, tend to have higher proportion of minorities and live farther away from nearest supermarket.

Aim 2: To examine if diet quality is associated with food-desert resident status.

Hypothesis:

Living in food-deserts would be associated with consumption of lower quality diets, as characterized by lower proportion meeting 5-A-Day recommendation, lower frequency of fruit and vegetable consumption and higher consumption of soda, snacks and sweets. These associations would persist even after taking socio-demographic variables and other covariates into account.

Aim 3: To examine the association between obesity as measured by BMI and obesity (BMI >30) and food desert residence.

Hypotheses:

- Food desert residents would be associated with higher BMI as compared to non-food desert residents, before and after adjusting for socio-demographic and lifestyle variables
- A higher percentage of food desert residents would be obese (BMI >30) compared to non-food desert residents, even after taking covariates into account.

METHODS AND PROCEDURES

This study is a secondary data analysis of the Seattle Obesity Study (SOS).

Seattle Obesity Study: The Parent Study

The Seattle Obesity Study was a population-based study of food environment, diets and health, based on a representative sample of 2,001 adult residents of King County, Washington. A stratified sampling scheme ensured adequate representation by income range and race/ethnicity. King County zip codes with high percentages of household incomes greater than \$35,000, African-Americans, or Hispanics were over-sampled. Randomly generated telephone numbers were matched with residential addresses using commercial databases. A pre-notification letter was mailed out to alert household members that they had been selected at random to participate in a study conducted by the University of Washington's School of Public Health.

SOS involved four data collection instruments:

1. Telephone survey
2. Food Frequency Questionnaire (FFQ)
3. Market basket data
4. Geocoded home, work and locations of food sources to develop objective network distance measures

Telephone Survey

Once the household from the sampling frame was randomly contacted, an adult member of the household over eighteen years old was randomly selected to be the survey respondent. Eligibility criteria were age eighteen or older and concordance between the address obtained from the vendor and that reported by the respondent. A twenty minute telephone survey was then administered to 2,001 respondents by trained and computer-assisted interviewers. The telephone survey collected individual-level data on food shopping and eating habits, two food shopping destinations primarily used by respondents along with data on names, location, frequency of visits, mode of transportation and food

expenditures at each of these stores. Respondents also reported the frequency of consuming a series of foods based diet quality question adapted from the national survey, Behavioral Risk Factor Surveillance System (BRFSS). Self-reported data on socio-demographic variables, health outcomes, and home and work locations were also collected for each respondent.

Food Frequency Questionnaires

Those respondents who completed the telephone survey were also asked to complete a written dietary intake survey, Food Frequency Questionnaire (FFQ). The response rate was 95% and completion rate was 66% (1318 out of 2001 respondents). Data from FFQ instrument was not relevant for the purpose of the present study, hence; it will not be discussed in further detail.

Market Basket Data

The SOS market basket, adapted from the Consumer Price Index and Thrifty Food Plan Market Baskets, contained 100 commonly consumed foods and beverages. These included a selection of healthful and less healthful foods. The purpose of this market basket was to collect data on availability and prices of each of these food items from commonly used food stores in King County area. Standardized criteria were developed to collect food prices. The total cost of the market basket was the sum of the prices of all 100 foods. Detailed methodology on this instrument and data collection procedures have been published already (Mahmud et al, 2009; Monsivais and Drewnowski, 2007; Drewnowski et al, 2012).

Geocoding data to develop network distance measures

Detailed procedures on geocoding SOS data to develop objective distance measures has already been published (Drewnowski et al, 2012) and discussed here briefly.

Geocoding Home and Food Source Locations

As part of SOS, home location of each respondent was geocoded to the centroid of the home parcel using the 2008 King County Assessor parcel data, using standard methods in ArcGIS 9.3.1 (ESRI, Redlands, CA). Full-service supermarkets, identified from the 2008 food establishment permits provided

by Public Health- Seattle & King County (PHSKC), were also geocoded matched to King County parcel centroids, using ArcGIS, version 9.3.1 (ESRI, Redlands, CA).

Street Network Distance Measures

Distance measures were computed from each respondent's home to the nearest supermarket and to the supermarket that was reported to be the primary food source. Network distance was calculated in ArcGIS 9.3.1 using ESRI StreetMap Premium North America NAVETQ 2009 Release 1. Network distances (in miles) represented the fastest route subjects would likely drive from home to the nearest or to the primary supermarket they used along the existing road network.

The SOS population sample (n=2001) was demographically comparable to the 2007 BRFSS data and was representative of King County population using 2000 US Census data. All the study protocols were approved by Institutional Review Board at University of Washington.

The Present Study: A Secondary Data Analysis of the Seattle Obesity Study

This study was a secondary data analysis of the SOS designed to examine associations between key socio-demographic variables, supermarket type frequented, diet quality and obesity among food - desert and non-food desert residents in King County, WAs. Data from the telephone survey, market basket tool and objective distance measures were utilized to assess the above mentioned associations. The variables utilized are described in the following sections.

Socioeconomic and Demographic Measures

The main SES variables of further interest are income and education. Income was originally categorized by six levels. This was condensed into three levels (\leq \$50,000, \$50,000 - $<$ \$100,000, \geq \$100,000) for analytical purposes. Education was defined as three categories (\leq High School, Some College, \geq College Degree) Additional variables used to describe the demographics of the SOS population were age, gender, race/ethnicity and household size. Age was self-reported by participants and was squared in order to account for the non-linear effects of age on health outcomes. Gender, race and

household size were also self-reported. Race was recoded into two categories (White, Non-White) for analytical purposes. All variables were obtained from the telephone survey of the SOS.

Food Desert Status

Secondary analysis of the dataset required the identification of SOS participants who reside in census tracts identified to be food deserts by the USDA. Food deserts were determined using the USDA Food Desert Locator tool (USDA, 2011). The census tract's Federal Information Processing Standards (FIPS) number was used to identify SOS participants residing in food deserts. Within King County, Washington, 17 census tracts were identified as food deserts. Of the 2,001 total SOS participants, 155 resided in King County food deserts, while 1,828 resided in non-food desert census tracts. 18 participants were not included, as their residence could not be geocoded and assigned a specific census tract. Participants were then appropriately coded based on their residence in a food desert or non-food desert census tract.

Diet Quality Measures

Diet quality measures of interest were meeting 5-A-Day fruit and vegetable recommendations, frequency of fruits and vegetables and frequency of sodas, sweets and snacks. Meeting 5-A-Day recommendations was derived from frequency questions included in the telephone survey. From these frequency questions about consumption of fruits and vegetables, it was calculated whether the participant was consuming 5 servings of fruits or vegetables. Frequency of fruits and vegetables was also calculated using frequency question included in the telephone survey. Frequency of sodas, sweets and snacks was a variable that combined the individual values for frequency of sodas, frequency of sweets and frequency of snacks into one variable for analytical purposes. The frequency of each individual variable was simply added together to create the singular variable. Outliers for all variables were taken into account.

Health Outcome Measures

The health outcomes of interest were BMI and obesity ($BMI \geq 30$). BMI was calculated using self-reported height and weight data from the telephone survey. Obesity was defined as a calculated BMI

of 30 or greater. To adjust for outliers among health outcomes, BMIs of 60 and greater were dropped from the dataset.

Network Distance Measures from Home to the Nearest and Primary Supermarket

The distance measures of interest were distance (in miles) from home to primary supermarket reported, distance (in miles) from home to the nearest supermarket and difference in distance (in miles) between primary supermarket reported and nearest supermarket. These objective distance measures were obtained using geocoding techniques and are further discussed in the previous “geocoding home and food source locations” section of this paper.

Classification of Supermarket Type by Price

Out of 1,480 respondents, 1,304 (88%) reported using supermarkets as their primary store for food shopping, which constituted the sample for analyses. Market basket data were collected in person from eight stores identified as primary food sources by 88% of the sample (n = 1,146 out of 1,304): Safeway, Fred Meyer, Quality Food Centers (QFC), Puget Consumer Co-op (PCC), Albertsons, Trader Joe’s, Whole Foods and Metropolitan Market. Details on prices collected have already been published (Mahmud et al, 2009; Drewnowski et al, 2012). Results showed that the availability of foods was close to 100% across all stores; however, there was a significant variation by price. Cluster analyses allowed us to stratify supermarkets into three groups by price – low, medium and high price. The average prices of the market basket among low price supermarkets was \$224, with the medium price being 30-40% more expensive and high price being 60-70% more expensive. Another 12% of the SOS sample available for analyses reported five more stores as their primary source for food shopping. To classify each of these stores into an appropriate price level, prices were either collected from the web or through contact with the store managers.

The variable of interest was supermarket affordability as defined by market basket price. Out of 1,302 participants, 385 (29%) shopped at low price supermarkets and 766 (59%) participants shopped at

mid-range, affordable supermarkets as their primary food store. Only 151 (12%) participants shopped at supermarkets that were identified as being expensive.

Statistical Analysis

Descriptive statistics were used to describe the overall sample, food-desert and non-food desert residents by key socio-demographic variables, distance to supermarkets; supermarket type frequented by price, multiple measures of diet quality and obesity. Descriptive statistics included chi-squared tests for categorical variables and two-sided t-tests for continuous variables. Means were computed for continuous variables and proportions for categorical variables. Standard deviations and proportions were also used to calculate supermarket type by price variables included in Appendix A.

Bivariable and multivariable regression analyses were conducted to examine diet quality by SES and food desert status. The final analytical sample for this aim was 1,545 participants, after taking missing values into account. The dependent variables of interest were each – meeting the 5-A-Day recommendation, frequency of fruits or vegetables consumption per day and frequency of sodas, snacks and sweets consumption per day. The main independent variable was food-desert status. Covariates were age, gender, race, household size, income and education.

Bivariable and multivariable regression analyses were repeated to examine if BMI and obesity were each associated with food-desert status. The dependent variables of interest were BMI and obesity ($\text{BMI} > 30 \text{ Kg/m}^2$) while the main independent variable was food-desert status. . Covariates were age, gender, race/ethnicity, household size, income, education, smoking status and physical activity.

All statistical analyses were completed using Stata 12.0 software (StataCorp LP, College Station, TX). A p-value of 0.05 was used to define statistical significance *a priori*. Logistic regression was used for bivariate and multivariate analysis of categorical variables such as obesity. Linear regression was utilized for continuous variables such as BMI.

RESULTS

Aim 1: Distribution of Food-Desert and Non-Food Desert Residents by Socio-Demographic Variables, Supermarket Types Frequented, Distance Traveled to Supermarkets, Diet Quality Measures and Obesity

Of the 1,550 participants available for analyses, 123 (8%) resided in a USDA identified food desert. Distribution of food-desert and non-food desert residents by key socio-demographic variables is presented in **Table 1A**. Majority of the sample were females (~60%) and Whites (~81%). No significant differences were observed by gender and race among food-desert and non-food desert residents. By income, relatively higher proportion of food-desert residents had annual household income of <\$35,000 (28% vs. 23% among non-food desert residents) and much lower proportion with income >=\$100K (18% vs. 27%). Similar trends were observed by education. Significantly lower proportion of food desert residents was college graduates (46%) as compared to non- food desert residents (58%) (p-value <0.05).

Table 1A: Distribution of Food Desert and Non-Food Desert Residents by Socio-Demographic Variables

Variable	Total	Food Desert (n = 123) Total (%)	Non-Food Desert (n = 1427) Total (%)	p value
Gender				0.374
Female	928	69 (56%)	859 (60%)	
Male	622	54 (44%)	568 (40%)	
Race				0.982
White	1259	100 (81%)	1159 (81%)	
Non-White	291	23 (19%)	268 (19%)	
Income				0.094
<= \$35,000	608	34 (28%)	327 (23%)	
\$35,000 to < \$100,000	542	67 (54%)	717 (50%)	
>= \$100,000	400	22 (18%)	378 (27%)	
Education				0.046
<= High School	262	26 (21%)	236 (17%)	
Some College	405	40 (33%)	365 (26%)	
>= College Degree	883	57 (46%)	826 (58%)	

Car ownership did not appear to be an issue in the present sample (**Table 1B**). Most of the respondents had at least one car in the household. In terms of type of primary store used for food

shopping, supermarkets predominated both among food-desert (89%) and non-food desert residents (88%) vs. other stores. Distribution by type of supermarket frequented was interesting. Significantly higher proportion of food-desert residents used low-cost supermarkets for food shopping (38% vs. 29% among non-food desert residents). By contrast, only 3% of the food-desert residents used high-cost supermarkets as compared to 12% of non-food desert residents (p-value <0.05).

Table 1B: Distribution of Food Desert and Non-Food Desert Residents by Food Access Variables

Variable	Total	Food Desert	Non-Food Desert	p value
		(n = 123) Total (%)	(n = 1427) Total (%)	
Number of Cars in Household				0.053
None	106	5 (4%)	101 (7%)	
One	533	52 (42%)	481 (34%)	
Two	618	41 (33%)	577 (40%)	
Three	210	14 (12%)	196 (14%)	
Four or More	81	11 (9%)	70 (5%)	
Primary Food Store Reported				0.664
Supermarkets only	1304	101 (89%)	1203 (88%)	
Other Stores ¹	176	12 (11%)	164 (12%)	
Supermarket Type by Price	1302	n = 97	n = 1205	0.010
Low Price	385	37 (38%)	348 (29%)	
Medium Price	766	57 (59%)	709 (59%)	
High Price	151	3 (3%)	148 (12%)	

¹. Other stores include grocery stores, warehouse stores, ethnic stores and food markets

The present study was unique in providing network distance from home to the nearest supermarket as well as primary supermarket by food desert status (**Table 1C**). Food desert residents lived farther away from their nearest supermarket on average (mean distance was 1.4 miles among food desert vs. 1.1 miles among non-food desert residents). However, mean distance traveled to the primary supermarket was much longer for both food desert and non-food desert residents (2.9 miles and 2.49 miles respectively).

Table 1C: Distribution of Food Desert and Non-Food Desert Residents by Distance Variables

Variable		Food Desert (n=123)	Non-Food Desert (n=1422)	<i>p</i> value
Network Distance (in miles) From Home to the Nearest Supermarket				
Mean ± SD	1545	1.4±0.6	1.1 ±0 .8	<0.001
Median (IQR)	1545	1.4 (1.0, 1.8)	0.9 (0.5, 1.4)	
Network Distance (in miles) From Home to Primary Supermarket Reported				
Mean ± SD	1545	2.9 ± 2.5	2.49 ± 2.6	0.129
Median (IQR)	1545	1.8 (1.4, 4.1)	1.8 (0.9, 3.2)	

Diet quality was measured using multiple indicators. Proportion of respondents consuming 5-A-Dzy (fruits or vegetables consumed at least five times per day) was ~30% and was similar across food-desert and non-food desert residents (**Table 1D**). In terms of continuous measures of diet quality, frequency of daily consumption of fruits or vegetables was on average 4.0±1.9 and was similar by food desert status. Similarly, no significant differences were observed among food-desert and non-food desert residents by daily consumption of sodas, snacks and sweets; salads; carrots and potatoes. Milk consumption among food desert residents was found to be significantly higher (*p* value <0.05) but no further information was available on the type of milk consumed.

Table 1D: Distribution of Food Desert and Non-Food Desert Residents by Diet Quality Measures

		Food Desert (n = 123)	Non-Food Desert (n = 1427)	
<i>FOR CATEGORICAL MEASURE</i>				
Variable	Total	Total (%)	Total (%)	p value
5-A-Day Consumption¹				0.667
	Yes	465	39 (32%)	426 (30%)
	No	1085	84 (68%)	1001 (70%)
<i>FOR CONTINUOUS MEASURES</i>				
	Total	Mean ± SD	Mean ± SD	p value
Frequency of Fruits or Vegetables Consumption per Day	1550	4.0 ± 1.9	4.2 ± 2.1	0.205
Frequency of Sodas, Snacks and Sweets Consumption per Day	1550	1.0 ± 1.13	1.0 ± 1.0	0.626
Frequency of Salad Consumption Per Day	1545	0.5 ± 0.0	0.5 ± 0.0	0.403
Frequency of Carrot Consumption Per Day	1545	0.3 ± 0.0	0.4 ± 0.0	0.176
Frequency of Milk Consumption Per Day	1543	0.7 ± 0.1	0.5 ± 0.0	0.021
Frequency of Potato Consumption Per Day	1545	0.2 ± 0.0	0.2 ± 0.0	0.808

¹Consumes fruits or vegetables at least five times per day

Smoking and physical activity were used as lifestyle measures. A higher percentage of food desert residents (55%) had smoked sometime during their lives; however, physical activity outside work was similar (79%) (**Table 1E**). In terms of health outcome, mean BMI was significantly higher among food-desert residents ($27.8 \pm 6.2 \text{ Kg/m}^2$) as compared to non-food desert residents. Proportion obese showed similar trends (30% among food desert residents vs. 20% among non-food desert residents) (p-value <0.05).

Table 1E: Distribution of Food Desert and Non-Food Desert Residents by Health Variables

		Food Desert (n = 123)		Non-Food Desert (n = 1427)		
<i>FOR CATEGORICAL MEASURE</i>						
Independent Variables		Total	Total (%)	Total (%)		p value
Ever Smoked						0.038
	Yes	718	68 (55%)	650 (46%)		
	No	832	55 (45%)	777 (54%)		
Physical Activity in the Past Month						0.991
	Yes	1223	97 (79%)	1126 (79%)		
	No	327	26 (21%)	301 (21%)		
Obese (BMI \geq 30 kg/m²)						0.016
	Yes	322	36 (30%)	286 (20%)		
	No	1228	87 (71%)	1141 (80%)		
<i>FOR CONTINUOUS MEASURES</i>						
Independent Variable		Mean \pm SD		Mean \pm SD		p value
BMI (Continuous)		1550	27.8 \pm 6.23	26.4 \pm 5.4		0.007

Aim 2: Bivariate and Multivariate Associations of Food-Desert Status with Multiple Measures of DietQuality

Analyses of diet quality measures showed that relatively higher proportion of women tend to meet the 5-A-Day recommendation (**Table 2A**). Participants who have completed college are also very significantly more likely to consume fruits and vegetables. Among participants who meet recommendations to consume 5 servings of fruits or vegetables, no significant trends were identified.

Table 2A: Distribution of Meeting 5-A-Day Recommendation by Key Socio-Demographic and Food Desert Variables.

Independent Variables	Total	Yes Total (%)	No Total (%)	p value
Overall	1545	462 (30%)	1083 (70%)	NA
Gender				<0.001
Female	925	314 (68%)	611 (56%)	
Male	620	148 (32%)	472 (44%)	
Race				0.348
White	1256	369 (80%)	887 (82%)	
Non-White	289	93 (20%)	196 (18%)	
Income				0.122
<= \$50,000	605	176 (38%)	429 (40%)	
\$50,000 to < \$100,000	540	178 (39%)	362 (33%)	
>= \$100,000	400	108 (23%)	292 (27%)	
Education				<0.001
<= High School	260	61 (13%)	199 (18%)	
Some College	404	92 (20%)	312 (29%)	
>= College Degree	881	309 (67%)	572 (53%)	
Food Desert Status				0.649
Non-Food Desert	1422	423 (92%)	999 (92%)	
Food Desert	123	39 (8%)	84 (8%)	

Frequency of fruits or vegetables consumption analysis (**Table 2B**) shows that once again, women are more likely to consume more fruits or vegetables than men. Those who have completed college consume approximately .8 servings more than their high school or less educated counterparts. Interestingly, participants earning between \$50,000 and \$100,000 significantly consumed a higher number of fruits or vegetables than other income brackets. Those making below \$50,000 consumed about .4 servings less. Differences among participants residing in food deserts were not significant.

Table 2B: Distribution of Frequency of Fruits or Vegetables Consumption per Day by Key Socio-Demographic Variables and Food Desert Variable.

Independent Variables		Total	Mean ± SD	p value
Overall		1545	4.2 ± 2.1	NA
Gender				<0.001
	Female	925	4.4 ± 2.1	
	Male	620	3.8 ± 2.0	
Race				0.242
	White	1256	4.2 ± 2.0	
	Non-White	289	4.3 ± 0.1	
Income				<0.001
	≤ \$50,000	605	4.0 ± 0.1	
	\$50,000 to < \$100,000	540	4.4 ± 0.1	
	≥ \$100,000	400	4.2 ± 0.1	
Education				<0.001
	≤ High School	260	3.7 ± 0.1	
	Some College	404	3.8 ± 0.1	
	≥ College Degree	881	4.5 ± 0.1	
Food Desert Status				0.204
	Non-Food Desert	1422	4.2 ± 2.1	
	Food Desert	123	4.0 ± 1.9	

Analysis of participants who consumed items such as sodas, snacks and sweets (**Table 2C**) that is normally associated with a poor diet revealed no differences in race or food desert status. Men consumed more sodas, snacks and sweets than women. Participants who earn \$50,000 or less also consume approximately .2 more sodas, snacks and sweets than any other income bracket. Those with a high school or less education also consumed more of these items than those who completed college. No other significant trends were noted.

Table 2C: Distribution of Frequency of Sodas, Snacks and Sweets Consumption per Day by Key Socio-Demographic Variables and Food Desert Variable.

Frequency of Sodas, Snacks and Sweets Consumption per Day			
Independent Variables	Total	Mean ± SD	p value
Overall	1545	1.0 ± 1.1	NA
Gender			<0.001
Female	925	0.9 ± 0.9	
Male	620	1.1 ± 1.2	
Race			0.690
White	1256	1.0 ± 1.1	
Non-White	289	1.0 ± 1.0	
Income			<0.001
≤ \$50,000	605	1.1 ± 0.0	
\$50,000 to < \$100,000	540	.9 ± 0.1	
≥ \$100,000	400	.9 ± 0.1	
Education			<0.001
≤ High School	260	1.2 ± 0.1	
Some College	404	1.0 ± 0.1	
≥ College Degree	881	.9 ± 0.0	
Food Desert Status			0.641
Non-Food Desert	1422	1.0 ± 1.0	
Food Desert	123	1.0 ± 1.1	

Model 1, bivariate analysis of meeting the 5-A-Day recommendation (**Table 2D**) revealed significant differences in those who make \$100,000 or more per year and those who have completed college when adjusted for age, gender, race/ethnicity, and household size. Individuals making \$100,000 were less likely to meet the 5-A-Day recommendation, while a college degree or higher academic achievement were more than twice as likely to meet the recommendation. Food desert status was not significant. These associations remained unchanged in multivariate analysis of the same 5-A-Day recommendation even after adjusting for Model 1 covariates in addition to income, education and food desert status. Food desert status did not affect this measure of diet quality.

Table 2D: Multi-variable Analysis of Food Desert Status by Meeting 5-A-Day Recommendation Adjusted by Covariates

Meeting 5-A-Day Recommendation		<i>Model 1 Bivariate^a</i>			<i>Model 2 Multivariate^b</i>		
Independent Variables		OR	95% CI	p value	OR	95% CI	p value
Food Desert Status							
	Non-Food Desert	Reference			Reference		
	Food Desert	1.12	0.8 – 1.7	0.563	1.1	0.8- 1.8	0.359
Income							
	<= \$50,000	Reference			Reference		
	\$50,000 to < \$100,000	1.0	0.8 – 1.4	0.731	1.1	0.8 – 1.4	0.718
	>= \$100,000	0.7	0.5 - .09	0.020	0.7	0.5 – 1.0	0.024
Education							
	<= High School	Reference			Reference		
	Some College	1.0	0.7 – 1.5	0.854	1.0	0.7 – 1.5	0.856
	>= College Degree	2.1	1.5 – 2.9	<0.001	2.1	1.5 – 3.0	<0.001

^aModel 1: Adjusted for age + gender + race/ethnicity + household size

^bModel 2: Mutually adjusted for model 1 + food desert status + income + education

Bivariate analysis of the frequency of fruits or vegetables consumption per day revealed similar results (**Table 2E**). The association between income and fruit or vegetable consumption was confirmed, but those between \$50,000 and \$100,000 per year are associated with consuming more fruits and vegetables than their lower and higher income counterparts. Attainment of a college degree was associated with a .9 increased frequency of fruits or vegetable consumption. Model 2, multivariate analysis confirmed these associations despite adjusting for model 1 covariates in addition to food desert status, income and education. Food desert status remained insignificant.

Table 2E: Multi-variable Analysis of Food Desert Status by Frequency of Fruit or Vegetable Consumption per Day Adjusted by Covariates

Frequency of Fruits or Vegetables Consumption per Day		<i>Model 1 Bivariate^a</i>			<i>Model 2 Multivariate^b</i>		
Independent Variables	Coef	95% CI	p value	Coef	95% CI	p value	
Food Desert Status							
Non-Food Desert	Reference			Reference			
Food Desert	-0.2	0.6 – 0.2	0.265	-0.1	-0.5 – 0.3	0.551	
Income							
<= \$50,000	Reference			Reference			
\$50,000 to < \$100,000	0.3	0.0 – 0.5	0.040	0.3	0.0 – 0.5	0.041	
>= \$100,000	-0.8	-0.4 – 0.2	0.575	-0.1	-0.4 – 0.2	0.560	
Education							
<= High School	Reference			Reference			
Some College	0.1	-0.2 – 0.5	0.403	0.1	-0.2 – 0.5	0.405	
>= College Degree	0.9	0.6 – 1.2	<0.001	0.9	0.6 – 1.2	<0.001	

^aModel 1: Adjusted for age + gender + race/ethnicity + household size
^bModel 2: Mutually adjusted for model 1 + food desert status + income + education

Model 1, bivariate analysis of the frequency of sodas, snacks or sweets consumption per day again revealed similar results as well (**Table 2F**). Income and education remain important predictors of diet quality. Incomes above \$50,000 are associated with lower consumption of sodas, snacks or sweets. Educational attainment above high school is also associated with a significantly lower frequency of consumption. These values remain the same after model 2, multivariate analysis and adjustment for food desert status, income and education. Food desert status remains an insignificant predictor of diet quality.

Table 2F: Multi-variable Analysis of Food Desert Status by Frequency of Sodas, Snacks or Sweets Consumption per Day Adjusted by Covariates

Frequency of Sodas, Snacks and Sweets Consumption per Day		<i>Model 1 Bivariate^a</i>			<i>Model 2 Multivariate^b</i>		
Independent Variables		Coef	95% CI	p value	Coef	95% CI	p value
Food Desert Status							
Non-Food Desert		Reference			Reference		
Food Desert		0.0	-0.2 – 0.2	0.763	0.0	-0.2 – 0.2	0.959
Income							
<= \$50,000		Reference			Reference		
\$50,000 to < \$100,000		-0.2	-0.3 – -0.1	0.003	-0.2	-0.3 - -0.1	0.003
>= \$100,000		-0.3	-0.4 - -0.2	0.001	-0.3	-0.4 - -0.1	0.001
Education							
<= High School		Reference			Reference		
Some College		-0.2	-0.4 - -0.3	0.017	-0.2	-0.4 - -0.0	0.018
>= College Degree		-0.2	-0.4 - -0.1	0.009	-0.2	-0.4 - -0.1	0.009

^aModel 1: Adjusted for age + gender + race/ethnicity + household size
^bModel 2: Mutually adjusted for model 1 + food desert status + income + education

In terms of the association between the diet quality measures mentioned above and food desert status, results consistently showed that food desert status is not associated with diet quality measures.

Aim 3: Bivariate and Multivariate Analyses of Food-Desert Status with BMI and Obesity Variables

Mean BMI of the sample was $26.4 \pm 5.2 \text{ Kg/m}^2$. Significant trends were observed by most of the socio-demographic variables (**Table 3A and 3B**). Mean BMI for men was 1.2 kg/m^2 higher than women. BMI was significantly lower among those with higher income (mean of 25.6 kg/m^2 among those with annual household income of $\geq 100\text{K}$ vs. 26.9 among those $< 50\text{K}$) and higher education (mean BMI of 26.1 Kg/m^2 among college graduates vs. 27.3 among high school or less). Similar results were obtained with obesity. Similar trends were observed by smoking and physical activity. Living in a food desert was associated with significantly higher BMI (27.8 Kg/m^2) as compared to non-food desert residents. Utilizing a low price supermarket was associated with a significantly higher BMI than those who shop at high price supermarkets (27.4 vs. 24.8 respectively).

Table 3A: Distribution of BMI by Key Socio-Demographic Variables and Food Desert Variable

BMI			
Independent Variables	Total	Mean ± SD	p value
Overall	1545	26.4 ± 5.2	NA
Gender			<0.001
Female	925	26.0 ± 5.5	
Male	620	27.2 ± 4.6	
Race			0.981
White	1256	26.5 ± 5.3	
Non-White	289	26.5 ± 4.6	
Income			<0.001
≤ \$50,000	605	26.9 ± 0.2	
\$50,000 to < \$100,000	540	26.6 ± 0.2	
≥ \$100,000	400	25.6 ± 0.3	
Education			<0.001
≤ High School	260	27.3 ± 0.3	
Some College	404	26.8 ± 0.3	
≥ College Degree	881	26.1 ± 0.2	
Ever Smoked			0.002
Yes	716	26.9 ± 0.2	
No	829	26.1 ± 0.2	
Physical Activity in the Last Month			<0.001
Yes	1220	26.0 ± 0.1	
No	325	28.2 ± 0.4	
Food Desert Status			0.003
Non-Food Desert	1422	26.4 ± 5.1	
Food Desert	123	27.8 ± 6.2	
Supermarket Type by Price			<0.001
Low Price	385	27.4 ± 0.3	
Medium Price	766	26.4 ± 0.2	
High Price	151	24.8 ± 0.4	

The average obesity rate of the sample was 21%. Significant trends were observed by most of the socio-demographic variables (**Table 3B**). Obesity rates were not significantly different among men and women (20% vs. 22% respectively), despite the trend of increased BMI seen in men (**Table 3A**). Lower obesity rates were seen among those with higher incomes (14% among those with annual household income of ≥100K vs. 20% among those <50K). Education revealed similar results among those with the

highest academic achievement (17% among college graduates vs. 28% among high school or less).

Similar trends were observed by smoking and physical activity. Living in a food desert was associated with higher percentages of obesity as compared to non-food desert residents. Shopping at low price supermarkets was also associated with higher percentages of obesity compared to those who shopped at high price supermarkets (27% vs. 9% respectively).

Table 3B: Distribution of Obese Classification by Key Socio-Demographic Variables and Food Desert Variable.

Obese (BMI\geq30)			
Independent Variables	Total	Yes Total (%)	p value
Overall	1545	319 (21%)	
Gender			0.200
Female	925	181 (20%)	
Male	620	138 (22%)	
Race			0.788
White	1256	261 (21%)	
Non-White	289	58 (20%)	
Income			<0.001
\leq \$50,000	605	158 (26%)	
\$50,000 to $<$ \$100,000	540	107 (20%)	
\geq \$100,000	400	54 (14%)	
Education			<0.001
\leq High School	260	72 (28%)	
Some College	404	95 (24%)	
\geq College Degree	881	152 (17%)	
Ever Smoked			0.005
Yes	716	170 (24%)	
No	829	149 (18%)	
Physical Activity in the Last Month			<0.001
Yes	1220	209 (17%)	
No	325	110 (34%)	
Food Desert Status			0.014
Non-Food Desert	1422	283 (20%)	
Food Desert	123	36 (29%)	
Supermarket Type by Price			<0.001
Low Price	385	105 (27%)	
Medium Price	766	158 (21%)	
High Price	151	13 (9%)	

Results from regression analyses are presented in **Tables 3C and 3D**. Lower income, living in food-deserts and shopping at lower-cost supermarkets were each associated with significantly higher BMI, adjusted for demographic and lifestyle variables (**Table 3C Model 1**). Multivariate analyses, after mutually adjusting for each other, confirmed the association between food desert status, supermarket type frequented and BMI (**Table 3C Model 2**). Living in a food desert was associated with 1.3 units higher BMI ($\beta = 1.3$, 95% CI: 0.00, 2.6), adjusting for socio-demographic variables and supermarket type. Similarly, shopping at high-cost supermarkets was associated with significantly lower BMI ($\beta = -2.0$, 95% CI: -2.9, -1.1), adjusting for covariates. Results remained the same with obesity as the outcome variable (**Table 3D**). Living in a food desert was associated with 1.7 times higher chance of being obese ($\beta = 1.7$, 95% CI: 1.1, 2.6), adjusting for socio-demographic and lifestyle variables and supermarket type (**Table 3D Model 2**). On the other hand, shopping at high-cost supermarkets was associated with 70% lower chance of being obese ($\beta = 0.3$, 95% CI: 0.2, 0.6), adjusting for covariates.

Table 3C: Multi-variable Analysis of Food Desert Status by BMI Adjusted by Covariates

BMI	<i>Model 1 Bivariate^a</i>			<i>Model 2 Multivariate^b</i>			
	Independent Variables	Coef	95% CI	p value	Coef	95% CI	p value
Food Desert Status							
	Non-Food Desert	Reference			Reference		
	Food Desert	1.3	0.4 – 2.3	0.005	1.3	0.0 – 2.6	0.042
Income							
	<= \$50,000	Reference			Reference		
	\$50,000 to < \$100,000	-0.1	-0.7 – 0.5	0.765	-0.2	-0.8 – 0.6	0.780
	>= \$100,000	-0.8	-1.6 - -0.1	0.026	-0.6	-1.4 - -0.3	0.210
Education							
	<= High School	Reference			Reference		
	Some College	-0.2	-1.0 – 0.6	0.624	-0.1	-1.1 – 0.8	0.761
	>= College Degree	-0.4	-1.2 – 0.3	0.261	-0.2	-1.1 – 0.7	0.637
Supermarket Type by Price							
	Low Price	Reference			Reference		
	Medium Price	-1.0	-1.7 - -0.4	0.001	-1.0	-1.6 - -0.3	0.005
	High Price	-2.2	-3.2 - -1.2	<0.001	-2.0	-2.9 - -1.1	<0.001

^aModel 1: Adjusted for age + gender + race/ethnicity + household size + smoking + physical activity

^bModel 2: Mutually adjusted for model 1 + food desert status + income + education + supermarket type by price

Table 3D: Multi-variable Analysis of Food Desert Status by Obese Classification Adjusted by Covariates

Obese	Variable	Model 1 Bivariate^a			Model 2 Multivariate^b		
		OR	95% CI	p value	OR	95% CI	p value
Food Desert Status							
	Non-Food Desert	Reference			Reference		
	Food Desert	1.6	1.0 – 2.5	0.024	1.7	1.1 – 2.6	0.023
Income							
	<= \$50,000	Reference			Reference		
	\$50,000 to < \$100,000	0.7	0.6 – 1.0	0.056	0.8	0.6 – 1.1	0.159
	>= \$100,000	0.5	0.4 – 0.8	0.001	0.6	0.4 – 0.9	0.024
Education							
	<= High School	Reference			Reference		
	Some College	0.9	0.6 – 1.3	0.542	0.8	0.5 – 1.2	0.338
	>= College Degree	0.8	0.5 – 1.1	0.176	0.8	0.5 – 1.2	0.303
Store Affordability							
	Low price	Reference			Reference		
	Medium Price	0.7	0.5 – 0.9	0.014	0.7	0.5 – 1.0	0.026
	High Price	0.3	0.2 – 0.5	<0.001	0.3	0.2 – 0.6	<0.001

^aModel 1: Adjusted for age + gender + race/ethnicity + household size + smoking + physical activity

^bModel 2: Mutually adjusted for model 1 + food desert status + income + education + supermarket type by price

DISCUSSION

This study provides a representative sample of King County, Washington residents who live and do not live in a census tract identified by the USDA's Food Desert Locator to be a food desert. Because this study was able to link the SOS database with food desert identified census tracts, it was possible to analyze individual-level SES measures of income and education with access to the nearest supermarkets. While previous studies (Walker et al, 2010) have accomplished the same analyses, this study has been able to expand the analysis to include distances to the actual supermarket that a participant frequents as their primary store. Previous research has made the assumption that residents shop at their nearest supermarket. This study has been able to link individual-level SES measures to food desert status in addition to linking self-reported height and weight (BMI calculated from these values) in addition to being able to associate self-reported diet quality measures with food desert status.

The descriptive analysis shows that food desert residents that participated in the SOS meet the USDA criteria for food deserts (Ver Ploeg et al, 2009). Food desert residents show a trend of earning less income than non-food desert residents. Unlike many other areas considered to be food deserts, the racial/ethnic composition of the food desert residents is not significantly different. Many studies have shown that areas that are more racially diverse are more likely to have fewer supermarkets (Moore and Diez-Roux, 2006; Zenk et al, 2006). However, residents of King County food deserts residents do indeed live farther away from their nearest supermarket by an average 0.3 mile.

This study shows that food desert residents in King County utilize supermarkets as their primary food store. This contrasts with research that speculates that food desert residents utilize convenience stores, ethnic food stores and corner food markets as their primary food store due to their close proximity (Short et al, 2007). These types of stores may be more closely located to a resident's home, but it seems as though they may only be used for supplemental food shopping.

Previous research shows that SOS participants do not shop at the closest supermarket to their home (Drewnowski et al, 2012). Instead of shopping at their closest supermarket, which would most

likely be a low price supermarket, 58% of food desert residents are shopping at medium price supermarkets than low price supermarkets. Furthermore, food desert residents have to travel an average 1.5 miles further to shop at their preferred supermarket. Sanae Inagami and colleagues (2006) found that less than 25% of individuals shop in the same census tract as their home. Lowest rates were among Asians and African Americans, but only 23% of White residents shopped within their census tract.

Analysis of diet quality measures showed no significant difference among food desert residents. Income and education are associated with higher fruit or vegetable consumption, and lower frequency of sodas, snacks or sweets consumption. This study's hypothesis assumed that because food desert residents were more likely to have a lower income, they would not be able to afford a high quality diet. Diet quality and the cost of higher quality foods have been implicated by numerous studies (Wolongevicz et al, 2010; Quatromoni et al, 2006; Drewnowski and Specter, 2004), but this study's results show no differences in diet quality despite trending income differences. Bivariate and multivariate analysis revealed that food desert status was not a predictor of diet quality, but food desert status was a predictor of BMI and obesity after adjusting for individual-level key socio-demographic factors. Supermarket type by price was also a significant predictor of BMI and obesity.

These findings show that lack of access to supermarkets is not an issue for King County food desert residents and this may not be an issue for other food desert residents in the United States. 10% of this study's population did not own a car. The vast majority of participants owned a car and thus physical access to a supermarket is assumed to not be an issue. The USDA's food desert criterion assumes that low-income food desert residents do not own a car and so shop at their nearest supermarket (Ver Ploeg and Breneman, 2009). This assumption does not hold up in King County.

What is missing from the USDA criterion is personal preference. The current criteria defining a food desert may be flawed because it ignores customer preference (where the resident actually shops) and instead focuses on convenience (nearest supermarket). Residents may be willing to travel further in order to get better prices on food purchases or for other reasons. Our study shows that on average, all

participants, regardless of food desert status shopped at a supermarket that was further away from their nearest supermarket. So, access to the resident's preferred supermarket may be the real issue at hand here. SES factors may be influencing the mechanism of why certain residents choose certain supermarkets to shop at. Additional research is needed in this area to determine what SES factors predict food shopping behaviors among food desert residents.

Another mechanism that could explain the significant difference in obesity and BMI among food desert residents that is not explained by diet quality is the quality and quantity of food that is eaten outside of the home. Guthrie and colleagues (2002) concluded that approximately 32% of total calories consumed by Americans came from food prepared away from the home. In another study among children 7 to 17, it was found that close to 55% of their total calories originated from foods prepared away from the home (Zoumas-Morse et al, 2001). Diet quality as measured in this study may not be capturing the increased caloric consumption of non-home prepared foods because the overall number of fruits and vegetables were accounted for and not the preparation of such items. Consumption of fast foods, take out foods and restaurant meals should be investigated in further research for the influence on diet quality among food desert residents.

Limitations

Due to the cross-sectional study design employed by the SOS, the data collected and analyzed by this study cannot be used to establish a causal relationship. Additionally, long term health outcomes such as obesity may be captured more appropriately by a longitudinal study design. Another limitation is the small sample size of food desert residents (n=123 for descriptive analysis, n=97 for supermarket type by price analysis). Small sample sizes could have resulted in less power to detect statistical differences when they truly exist. In addition, food desert residents who participated in the SOS may not be representative of their resident census tracts. The speculation of researchers (IOM and NRC, 2009) that food desert research conclusions cannot be generalized to other locations and populations is a limitation that all food desert studies face.

CONCLUSION

This study analyzed individual level data to ascertain relationships between food desert residence and SES, store affordability, diet quality and obesity. Results show that residing in a food desert is not the key factor associated with obesity, but that socioeconomic status as defined by income and education are. Solving issues surrounding access to healthy fruits and vegetables may not be as easy as previously thought. Building a new supermarket in food deserts may solve issues of access relating to distance, but it may not solve the socioeconomic challenges facing food desert residents.

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APPENDIX A: Descriptive Analyses of Supermarket Type by Price

Analysis of supermarket type by price reveals that race and gender are insignificantly different, but that income, education and food desert status is highly significant (**Table A1**). A larger percentage (46%) of individuals earning \$50,000 or less per year, shop at low price supermarkets than individuals who earn \$50,000 or more per year. As income increases, the individual is more likely to be shopping at a higher priced supermarket. With education, we see the same effect; increasing academic achievement results in an individual being more likely to shop at higher price supermarkets. When considering food desert status and supermarket type by price, one needs to consider what percentage of food desert residents shop at low price supermarkets rather than the percentage of low price supermarket customers that are food desert residents. 38% of food desert residents shop at low price supermarkets, compared to only 23% of non-food desert residents. Three percent of food desert residents utilize a high price supermarket as their primary store compared to 12% of non-food desert residents.

Distance measures (**Table A2**) reveal that among primary supermarkets, medium price supermarkets are generally closer to residents. However, high price supermarkets are actually significantly closest to residents. If an individual wants to shop at a low price supermarket, that individual will have to travel significantly farther than their nearest supermarket in comparison to higher priced supermarkets.

Table A1: Distribution of Supermarket Type by Price by Key Socio-Demographic Variables

Supermarket Type by Price					
Variable	Total	Low Price Total (%)	Medium Price Total (%)	High Price Total (%)	<i>p</i> value
Overall	1302	385 (29%)	766 (59%)	151 (12%)	
Race					0.855
White	1075	316 (82%)	632 (83%)	127 (84%)	
Non-White	227	69 (18%)	134 (17%)	24 (16%)	
Gender					0.114
Female	796	233 (61%)	459 (60%)	104 (69%)	
Male	506	152 (39%)	307 (40%)	47 (31%)	
Income					<0.001
<= \$50,000	520	177 (46%)	305 (40%)	38 (25%)	
\$50,000 to < \$100,000	443	128 (33%)	253 (33%)	62 (41%)	
>= \$100,000	339	80 (21%)	208 (27%)	51 (34%)	
Education					<0.001
<= High School	227	88 (23%)	135 (18%)	4 (3%)	
Some College	329	124 (32%)	188 (24%)	17 (11%)	
>= College Degree	746	173 (45%)	443 (58%)	130 (86%)	
Food Desert Status					0.010
Non-Food Desert	1205	348 (90%)	709 (93%)	148 (98%)	
Food Desert	97	37 (10%)	57 (7%)	3 (2%)	

Table A2: Distribution of Supermarket Type by Distance Variables

Supermarket Type by Price					
Variable		Low Price Mean ± SD	Medium Price Mean ± SD	High Price Mean ± SD	<i>p</i> value
Distance (in miles) From Home to Primary Supermarket Reported	1275	3.4 ± 0.1	2.0 ± 0.1	2.6 ± 0.2	<0.001
Distance (in miles) From Home to the Nearest Supermarket	1302	1.2 ± 0.0	1.1 ± 0.0	0.8 ± 0.1	<0.001