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Access to supermarkets and fruit and vegetable consumption

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Abstract

Objective—Individual-level determinants of diets are well known. Recently, physical proximity to neighborhood supermarkets has been proposed as an environmental determinant of access to healthy foods, diets and health. The present study hypothesized that supermarket choice, conceptualized as the proxy for underlying personal factors, would better predict supermarket accessibility and diet quality than mere physical proximity.

Methods—The Seattle Obesity Study geocoded respondents' home addresses and locations of their primary supermarkets. Primary supermarkets were stratified into low-, medium- and high-cost according to the market basket cost of 100 foods. Data on fruit and vegetable consumption were obtained through telephone surveys. Linear regressions examined associations between physical proximity to primary supermarkets, supermarket choice, and fruit and vegetable consumption. Descriptive analyses examined whether supermarket choice outweighed physical proximity among lower-income and vulnerable groups.

Results—Only one-third of respondents shopped at their nearest supermarket for their primary food supply. Those who shopped at low-cost supermarkets were more likely to travel beyond their nearest supermarket. Fruit and vegetable consumption was not associated with physical distance but, with supermarket choice, after adjusting for covariates.

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Author contributions

AA, AJC, AVM, PMH and AD were involved in planning and implementation of the SOS. AA was involved in conceptualizing the manuscript, data analysis and interpretation, and led manuscript writing. AJC led data analysis and assisted in data interpretation. JJ and RS assisted in data analysis and data interpretation. AVM conceptualized and led the development of distance data. PMH was responsible for developing the distance variables. AD led the study, assisted in conceptualizing the manuscript, data interpretation and manuscript writing.

Human Participant Protection

All the study instruments and protocols were approved by Institutional Review Board at the University of Washington

Conclusions—Mere physical distance may not be the most salient variable to reflect access to supermarkets, particularly among those who shop by car. Studies on food environments need to focus beyond neighborhood geographic boundaries to capture actual food shopping behaviors.

INTRODUCTION

Socioeconomic disparities in diet quality are well established in the US. Lower income and education groups have been consistently linked with poor diets and health.[1,2] Multiple individual-level factors are known to influence diet quality such as economic barriers, inadequate nutrition knowledge and awareness, food preferences, attitudes and cultural factors.[2-6]

In the past decade, availability of healthy foods at the neighborhood level has been proposed as an environmental determinant of diet.[7-12] In the absence of data on actual food shopping destinations, assumption has been made that the availability of supermarkets reflect accessibility. Thus, physical proximity to neighborhood supermarkets, either based on aggregated data such as the presence[11,13,14] or density of supermarkets within a given neighborhood census tract[15-17], or on individual-level measures such as the distance between the home and the nearest supermarket, [13,16,18,19], have been linked with higher consumption of fruits and vegetables and with higher diet quality overall. Ensuring physical access to supermarkets in low income neighborhoods has recently become the focus of public health policy to improve diets and health[20,21].

However, a few recent studies have found inconsistent results[21-23]. Physical distance to a supermarket was not associated with fruit and vegetable intake, overall diet quality and body weight[22-24], even with varying distances from respondents' homes.[25,26] Interestingly, a few of these studies that probed for actual food shopping locations found that most people did not even shop at their nearest supermarkets.[22,23,27,28] Such studies are beginning to imply that physical proximity may not be the salient variable to determine accessibility to supermarkets and food shopping behaviors, particularly for those who shop by car.[26,29,30] Rather, a host of other proximal and distal determinants of dietary intake such as personal choices, psychosocial factors and unobserved measures of socioeconomic status have been proposed to determine food shopping decisions and in turn diets and health.[23,28]

The purpose of the present study was to examine whether physical proximity to supermarkets vs. underlying personal factors would more strongly predict accessibility to supermarkets and fruit and vegetable intakes. This is one of the very few studies with data on actual food shopping destinations, which allowed us to investigate this question. Novel measures were used to conceptualize each of these variables. First, physical proximity was measured by the street network distance between the home and the supermarket actually reported as primary food source by each respondent. Second, the choice of the primary supermarket was used as a proxy for unmeasured underlying personal factors such as economic and psychosocial barriers and food preferences. The present hypothesis was that supermarket choice, rather than physical distance to the primary supermarket, would better predict diet quality. The question was whether supermarket choice would outweigh physical proximity in predicting diet quality even for low-income or other vulnerable groups.

METHODS

Participants

The Seattle Obesity Study (SOS) was based on a stratified, population-based sample of 2,001 adult residents of King County, WA. Detailed methodology and study procedures have been published.[23,31] Telephone numbers were matched with residential addresses using a commercial database and pre-notification letters were mailed. Adult respondents were randomly selected from each household. Eligible respondents who provided verbal consent completed a 25-minute telephone survey modeled on Behavioral Risk Factor Surveillance System (BRFSS). The survey collected detailed individual-level data on fruit and vegetable consumption, food shopping and eating habits, and socio-demographic and health variables. The study was conducted during 2008-09. All the study protocols were approved by the UW Institutional Review Board.

Each respondent was asked to report the name of the primary food store at which most of the household food was purchased, as well as store location. The present analyses were conducted in 2011-12 and were restricted to the 1,670 participants who reported supermarkets as their primary store. After removing missing data, the final analytical sample consisted of 1,386 respondents.

Fruit and vegetable consumption as a measure of diet quality

During the telephone survey, respondents were asked to report the frequency of consuming whole fruits, 100% fruit juices, salads, potatoes, carrots and other vegetables (the standard diet quality questions used from BRFSS survey 2008-09[32]). The reported frequency of consumption for each of these items was combined to compute the daily intake of total fruit and vegetable intake by each respondent.

Geocoding and network distance measures

The home address of each respondent was obtained during the telephone survey. Each of these addresses were 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). Address records that failed the automatic geocoding (30%, using a 100% match score) were manually matched using a digital map environment with annotated layers from the reference data, augmented by online resources such as GoogleMaps. Each home point was double-checked by a separate technician for plausibility and accuracy. Detailed methodology has been published previously[23].

Data on all food store locations in King County were obtained from 2008 food permit records from Public Health- Seattle & King County (PHSKC). All food locations were geocoded to the centroid of the parcel using the 2008 King County Assessor parcel data, using standard methods in ArcGIS, version 9.3.1. Address records that failed the automatic geocoding (~12%, using a 60% match score) were manually matched using a digital map environment with annotated layers from the reference data, augmented by online resources such as GoogleMaps. A total of 10,215 of 10,254 (99.6%) of the food permit addresses were geocoded in 2009.

Network distances were computed from each respondent's home to all supermarkets in the data set, using ArcGIS 9.3.1 with ESRI StreetMap Premium NAVTEQ Street Data 2011 Release 2 for Washington State. Network distances (in miles) represented the fastest route subjects would likely drive from their homes to their primary supermarkets and nearest supermarkets along the existing road network. Based on the distribution of data obtained, distance to the primary supermarket variable was categorized into <1 mile, 1-<2 miles, 2-<3 miles, and >3 miles. We included the additional category of ≥3 miles because more than 25% of the study population traveled 3 or more miles to their primary store.

Further, respondents were stratified by those whose primary supermarkets were their nearest supermarkets vs. not. Those who reported using their nearest supermarket or supermarkets within 0.1 mile buffer were categorized as nearest supermarket users. The 0.1 mile buffer allows for the differentiation between those going to supermarkets within a couple of blocks from their nearest supermarket vs. those who truly traveled further in terms of time of travel and convenience for their primary supermarket of choice.

Characterizing supermarkets by market basket cost and availability

Market basket data of 100 commonly consumed foods was developed to characterize each of the primary supermarkets by food availability and price.[33] Detailed methodology on market basket procedures and classification of supermarkets has been previously published.[23,34] Data on food availability and prices were collected through in-person visits for eight supermarket chains reported by 90% of the sample, Safeway, Fred Meyer, Quality Food Centers (QFC), Puget Consumer Co-op (PCC), Albertsons, Trader Joe's, Whole Foods and Metropolitan Market. For each store, the lowest price available for each item in the market basket was used; most often this was the store brand price. For the remaining five stores reported by 10% of the sample, data were collected from the company websites or through contact with the store managers.

Availability of market basket foods was found to be close to 100% across all stores; however, there was a significant variation by price. Cluster analyses were used to classify supermarkets into three price strata: low, medium, and high. The average cost of market basket among low-cost supermarkets was $224, with the medium being 30-40% more expensive ($305 on average) and highest being 60% more expensive (average of $393).

Socioeconomic and demographic measures

Socio-demographic variables were collected during the telephone survey. Demographic variables of interest were age, gender, race/ethnicity, household size, car ownership and residential density. Annual household income and highest education completed were used as indicators of socioeconomic status. For analytical purposes, income was defined in two categories: < $50K and ≥ 50K. The six category education variable was also recoded into three categories: high school or less, some college, and college graduates or higher. Race/ethnicity was categorized into two categories: White non-Hispanics and other. Car ownership data was obtained from the telephone survey and was dichotomized. Residential density was obtained from the King County Assessor's parcel data and was calculated as the

number of dwelling units within a 10-minute walking radius (833 m), and was treated as a continuous variable for analyses.

STATISTICAL ANALYSES

The diet quality outcome measure, daily consumption of total fruits and vegetables, was summarized by socio-demographic variables, street network distance to the primary supermarket, and supermarket type by price. Means with standard deviations (SD) and medians with interquartile ranges (IQR) were computed.

A series of regressions were conducted to assess the relationship of fruit and vegetable consumption with network distance to the primary supermarket and supermarket type by price. Model 1 consisted of a set of linear regression analyses adjusting for age, gender, race/ethnicity, household size, residential density and car ownership. Frequency of fruits and vegetable consumption was used as the dependent variable while network distance to the primary supermarket, supermarket type, annual household income and education were each used as independent variables. Model 2 evaluated if supermarket type was still associated with consumption of fruits and vegetables after further adjusting for household income and education in a multivariable model. Model 3 examined if the observed relations persisted after adding the distance variable to the model.

Descriptive analyses were conducted to characterize the socio-demographic profile and supermarket choice of respondents who by passed their nearest supermarket for their primary food source vs. those who did not. We calculated omnibus *P* values assessing the overall unadjusted relationship between each demographic variable.

All regression models were performed using linear regression with robust standard errors to correct for the skewed dependent variable.[35] Sensitivity analyses were also conducted using log-linear regression models, which used the log of servings of fruits and vegetables as the outcome to assess the robustness of the primary results. For these log-linear regression models, we also evaluated if spatial correlation existed after adjusting for the baseline covariates. Based on the Akaike information Criteria (AIC[36]), models without including any spatial correlation had a better goodness of fit. The findings from all models remained the same; hence, only the results from linear regression were presented for ease of interpretation.

All CI and *P* values were two-sided based on the Wald statistic with statistically significant associations at $P<0.05$. Data analyses were conducted with R software (version 2.15.1).[37]

RESULTS

The sample was largely female (62%), White non-Hispanic (82%), with annual household income ≥ 50K (60%), and college graduates (56%) (Table 1). Most of the respondents owned at least one car (93%). By primary supermarket choice, about 30% of the sample shopped at low-cost supermarkets whereas 12% shopped at high-cost supermarkets.

In terms of food shopping locations, only one-third of the sample (33.3%) accessed their nearest available supermarket from home as their primary food source, while majority (66.6%) did not. For most of the respondents (74%), the network distance between the home and the primary supermarket was >1mile, and for 45% of respondents it was >2 miles.

Distribution of fruit and vegetable consumption by socio-demographic variables indicated that it was higher among women (4.36 times/d) than among men (3.89 times/d); it was higher among older >65y (4.29 times/d) than among young adults 18-44y (4.03 times/d) and among persons with higher education and incomes.

Fruit and vegetable consumption was also higher among shoppers at high cost supermarkets as compared to low cost supermarkets (4.83 times/d vs. 4.09). By contrast, there was no association between fruit and vegetable consumption and physical distance to the primary supermarket.

Multivariable analyses, adjusted for demographics, showed that higher income, higher education, and supermarket type were each associated with higher fruit and vegetable consumption ($p<0.05$ for each). However, physical distance to the primary supermarket was found to be unrelated (Table 2 Model 1). The observed positive relation between supermarket type and fruit and vegetable consumption strongly persisted even after adjusting for SES ($\beta = 0.56$, 95% CI: 0.10, 1.01; p-value = 0.017) (Model 2) and the distance variables ($\beta = 0.55$, 95% CI: 0.09, 1.01; p-value = 0.018) (Model 3).

The socio-demographic profile and supermarket choice of respondents who shopped at their nearest supermarket is shown in Table 3. No significant differences were observed by gender, age and SES variables (p-value >0.05 for each). However, a significant trend was observed by race. Only one quarter of non-Whites shopped at their nearest supermarket (26.6%), a proportion significantly lower as compared to Whites (35.3%) (p-value = 0.009). Analyses of shopping patterns by supermarket type revealed a significant relation (p-value <0.001). Only a small proportion of low- and high cost supermarket shoppers (25% and 30% respectively) reported their nearest supermarket as the primary store for food shopping, whereas majority of them traveled much further. Figure 1 depicts an example of the quickest routes from home to the primary supermarket for two same-area residents. Respondent A by-passed medium and high cost supermarkets that were in physical proximity to his/her home for the low-cost supermarket of choice. Similarly, respondent B by-passed medium and low cost supermarkets physically proximal to home to get to the high-cost supermarket chosen for primary food shopping.

DISCUSSION

This is one of the few US-based studies that, to our knowledge, collected data on actual food shopping locations used as primary food source by respondents and characterized respondents' choice of the primary store by price. There were several unique findings. First, contrary to common assumptions, the majority of the study respondents did not access their nearest supermarket as the primary food source. The nearest supermarket was the primary one for only one-third of the study respondents; the remaining two-third shopped for food

elsewhere. These findings imply that mere availability of supermarkets in the home neighborhood does not act as a proxy for accessibility by respondents, particularly among those with access to a car for food shopping. This could be one of the potential reasons for the observed inconsistency in the existing literature on physical proximity to supermarkets, diets and health.

Second, physical distance to the actual supermarket from home was not found to be linked to diet quality. This was not surprising considering that most of the people had access to cars for food shopping and could easily drive beyond food stores in physical proximity to their residence to reach the primary supermarket of their choice. While some studies had found no link between physical distance to home neighborhood supermarkets and diet quality,[25,26] the present study is the first to confirm these findings using the physical distance from homes to actual supermarkets that were used by respondents. Additional preliminary analyses indicated that the primary reported supermarket was not physically proximal even to the work location for 70% of the sample who reported to be employed (data not published yet).

Third, the choice of the primary supermarket was instead found to be strongly and significantly associated with fruit and vegetable intakes. Shoppers at low cost supermarkets had significantly lower intakes of fruits and vegetables as compared to shoppers at medium and high cost supermarkets, even after taking SES into account. It appears that food shopping behaviors characterized by the type of food shopping locations frequented may be more closely linked to dietary behaviors and health outcomes than the mere presence or absence of food sources within the home neighborhood boundaries. Our findings are consistent with Gustafson et al study, the only US-based study which, to our knowledge, linked food venue choice with diet quality.[28]

Characterizing respondents' primary food source by price provided unique insights into underlying unmeasured determinants of food shopping behaviors across socioeconomic groups. More low- and high-cost supermarket shoppers reported using a primary supermarket that was outside their immediate neighborhood than medium-cost shoppers. Interestingly, this phenomenon was observed even when the availability of healthy foods was similar across all supermarket chains[33], and despite the larger number of medium-cost supermarkets in the study area. We speculate that lower-income respondents selected a distant supermarket because of economic barriers, whereas the more affluent shoppers selected a more distant supermarket for food selection based on their food choices and lifestyles.

The present observations imply that access to supermarkets and food shopping behaviors of individuals are shaped by many underlying personal factors, rather than mere physical proximity. Such factors may range from unobserved measures of SES and economic barriers to dietary knowledge, food preferences and health status of household members, to attitudes and cultural factors. Characterizing respondents' primary supermarket of choice by price acted as a proxy for such underlying drivers of their food shopping behaviors and diet quality in the present study. It would be interesting to conduct analogous studies in situations when car transport is not available, or in rural areas where any supermarket is a considerable distance away.

Recent public health policies and initiatives aim to improve diets and health by ensuring physical availability and access to supermarkets, particularly in low-income areas[20,38]. The present findings have significant implications, particularly for the lower-income groups who were more likely to access their primary food source away from their home neighborhood food environment. Conceptualizing one's food shopping environment needs to move beyond physical proximity,[21-23,25,26,28] and must consider the complex array of other unobserved psychosocial, cultural and economic factors, which may influence supermarket choice, food spending, and in turn, diet quality and health.

This study had limitations. First, a majority of the respondents were car owners. Thus, the findings may be less relevant in less car-oriented settings. Second, respondents were classified into appropriate supermarket type based on self-reported primary food shopping locations. In the present sample, these stores accounted for 70% of the household reported food purchases (data not shown). Additional data are needed for people who use multiple food stores on a regular basis or multiple sources of food access such as delivery and eating out. Third, the present sample had a relatively low proportion of low-income, low-education, and minorities – characteristics of the Seattle population. We speculate that the associations observed among low-cost supermarket shoppers may become more pronounced with a higher representation of SES and minorities. Fourth, the diet quality variable was based on BRFSS data, which may not truly represent the intakes at the individual level. However, it is a useful tool to make comparisons across subjects. Fifth, this is a cross-sectional study, which limits our ability to draw any causal associations.

CONCLUSION

Supermarket choice, rather than physical proximity from respondent's home, predicted diet quality in the present sample. Physical proximity to supermarkets may not be the salient variable to reflect one's accessibility to supermarkets and food shopping environment, particularly among those with access to a car. The present findings suggest that food shopping decisions are constrained by more than geographic boundaries and may include underlying personal factors such as economic considerations, food preferences, attitudes and cultural factors. Public policies to locate supermarkets will be successful only if such underlying determinants are identified and actual food shopping patterns are known. Further research is needed to identify the salient features of food shopping patterns and food environment of individuals across socioeconomic and geographic strata.

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References

1. Kant AK, Graubard BI. Secular trends in the association of socio-economic position with self-reported dietary attributes and biomarkers in the US population: National Health and Nutrition Examination Survey (NHANES) 1971-1975 to NHANES 1999-2002. Public Health Nutr. 2007; 10(2):158–167. [PubMed: 17261225]

2. Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr. 2008; 87(5): 1107–1117. [PubMed: 18469226]
3. Inglis V, Ball K, Crawford D. Why do women of low socioeconomic status have poorer dietary behaviours than women of higher socioeconomic status? A qualitative exploration. Appetite. Dec; 2005 45(3):334–343. [PubMed: 16171900]
4. Beydoun MA, Wang Y. Do nutrition knowledge and beliefs modify the association of socio-economic factors and diet quality among US adults? Prev Med. Feb; 2008 46(2):145–153. [PubMed: 17698186]
5. Aggarwal A, Monsivais P, Cook AJ, Drewnowski A. Does diet cost mediate the relation between socioeconomic position and diet quality? Eur J Clin Nutr. May, Sep;2011 65(9):1059–66.10.1038/ejcn.2011.72 [PubMed: 21559042]
6. Ball K, Crawford D, Mishra G. Socio-economic inequalities in women's fruit and vegetable intakes: a multilevel study of individual, social and environmental mediators. Public Health Nutr. Aug; 2006 9(5):623–630. [PubMed: 16923294]
7. Healthy Eating Research. Research Brief. Robert Wood Johnson Foundation; Jul. 2008 Bringing healthy food home: Examining inequalities in access to food stores.
8. Morland K, Diez Roux AV, Wing S. Supermarkets, other food stores, and obesity. Am J Prev Med. 2006; 30(4):333–339. [PubMed: 16530621]
9. Bodor JN, Rice JC, Farley TA, Swalm CM, Rose D. The association between obesity and urban food environments. J Urban Health. May, Sep;2010 87(5):771–81.10.1007/s11524-010-9460-6 [PubMed: 20458548]
10. Treuhaft S, Karpyn A. The Grocery Gap: Who has access to healthy food and why it matters. Policy Link and The Food Trust. 2010
11. Morland K, Wing S, Roux AD. The contextual effect of the local food environment on residents' diets: The Atherosclerosis Risk in Communities Study. Am J Public Health. 2002; 92:1761–1767. [PubMed: 12406805]
12. Mikkelsen, L.; Chehimi, S. The links between the neighborhood food environment and childhood nutrition. Robert Wood Johnson Foundation; 2007.
13. Bodor JN, Rose D, Farley TA, Swalm C, Scott SK. Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. Public Health Nutr. Apr; 2008 11(4):413–420. [PubMed: 17617930]
14. Laska MN, Hearst MO, Forsyth A, Pasch KE, Lytle L. Neighbourhood food environments: are they associated with adolescent dietary intake, food purchases and weight status? Public Health Nutr. Nov; 2010 13(11):1757–1763. [PubMed: 20529405]
15. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR Jr. Associations of the local food environment with diet quality--a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. Am J Epidemiol. Apr 15; 2008 167(8):917–924. [PubMed: 18304960]
16. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Prev Med. 2004; 39(5):869–875. [PubMed: 15475018]
17. Wang MC, Cubbin C, Ahn D, Winkleby MA. Changes in neighbourhood food store environment, food behaviour and body mass index, 1981--1990. Public Health Nutr. Sep; 2008 11(9):963–970. [PubMed: 17894915]
18. Jago R, Baranowski T, Baranowski JC, Cullen KW, Thompson D. Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. Int J Behavioral Nutr and Phy Act. 2007; 4
19. Michimi A, Wimberly MC. Associations of supermarket accessibility with obesity and fruit and vegetable consumption in the conterminous United States. Int J Health Geogr. 2010; 9:49. [PubMed: 20932312]
20. Let's Move. [Aug 25th, 2012] Access to healthy, affordable food. http://www.letsmove.gov/sites/letsmove.gov/files/TFCO_Access_to_Healthy_Affordable_Food.pdf
21. Ploeg, MV. Economic Reseach Service Report. Washington, DC: USDA; 2010. Access to affordable, nutritious food is limited in "Food Deserts".

22. Caspi CE, Kawachi I, Subramanian SV, Adamkiewicz G, Sorensen G. The relationship between diet and perceived and objective access to supermarkets among low-income housing residents. Soc Sci Med. Oct; 2012 75(7):1254–1262. [PubMed: 22727742]
23. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and supermarket access: proximity or price? Am J Public Health. Jun, Aug;102(8):e74–80. [PubMed: 22698052]
24. An R, Sturm R. School and residential neighborhood food environment and diet among California youth. Am J Prev Med. Feb; 2012 42(2):129–135. [PubMed: 22261208]
25. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, Shikany JM, Lewis CE, Popkin BM. Fast food restaurants and food stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. Arch Intern Med. Jul 11; 2011 171(13):1162–1170. [PubMed: 21747011]
26. Hattori A, An R, Sturm R. Neighborhood food outlets, diet, and obesity among California adults, 2007 and 2009. Prev Chronic Dis. Mar.2013 10:E35. [PubMed: 23489640]
27. Inagami S, Cohen DA, Finch BK, Asch SM. You are where you shop: grocery store locations, weight, and neighborhoods. Am J Prev Med. Jul; 2006 31(1):10–17. [PubMed: 16777537]
28. Gustafson A, Christian JW, Lewis S, Moore K, Jilcott S. Food venue choice, consumer food environment, but not food venue availability within daily travel patterns are associated with dietary intake among adults, Lexington Kentucky 2011. Nutr J. 2013; 12:17. [PubMed: 23360547]
29. Chaix B, Bean K, Daniel M, et al. Associations of supermarket characteristics with weight status and body fat: a multilevel analysis of individuals within supermarkets (RECORD study). PLoS One. 2012; 7(4):e32908. [PubMed: 22496738]
30. Christian WJ. Using geospatial technologies to explore activity-based retail food environments. Spatial and spatio-temporal epidemiology. Dec; 2012 3(4):287–295. [PubMed: 23149325]
31. Moudon AV, Cook AJ, Ulmer J, Hurvitz PM, Drewnowski A. A neighborhood wealth metric for use in health studies. Am J Prev Med. Jul; 2011 41(1):88–97. [PubMed: 21665069]
32. Centers for Disease Control and Prevention (CDC). Behavioral Risk Factor Surveillance System Survey Questionnaire. Atlanta: Centers for Disease Control and Prevention; 2009.
33. Mahmud, NK.; Monsivais, P.; Drewnowski, A. The search for affordable nutrient rich foods: A comparison of supermarket food prices in Seattle-King County. Center for Public Health Nutrition, University of Washington; 2009 Jul.
34. Monsivais P, Drewnowski A. The rising cost of low-energy-density foods. J Am Diet Assoc. Dec; 2007 107(12):2071–2076. [PubMed: 18060892]
35. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. Biometrics. Mar; 1986 42(1):121–130. [PubMed: 3719049]
36. Sakamoto, Y.; Ishiguro, M.; Kitagawa, G. Akaike Information Criterion Statistics. D. Reidel Publishing Company; 1986.
37. R Core Team. R: A language and environment for statistical computing. Vienna, Australia: R Foundation for Statistical Computing; 2012.
38. Institute of Medicine, National Research Council. The Public Helth Effects of Food Deserts: Workshop Summary. Atlanta, GA: National Academic Press; 2009.

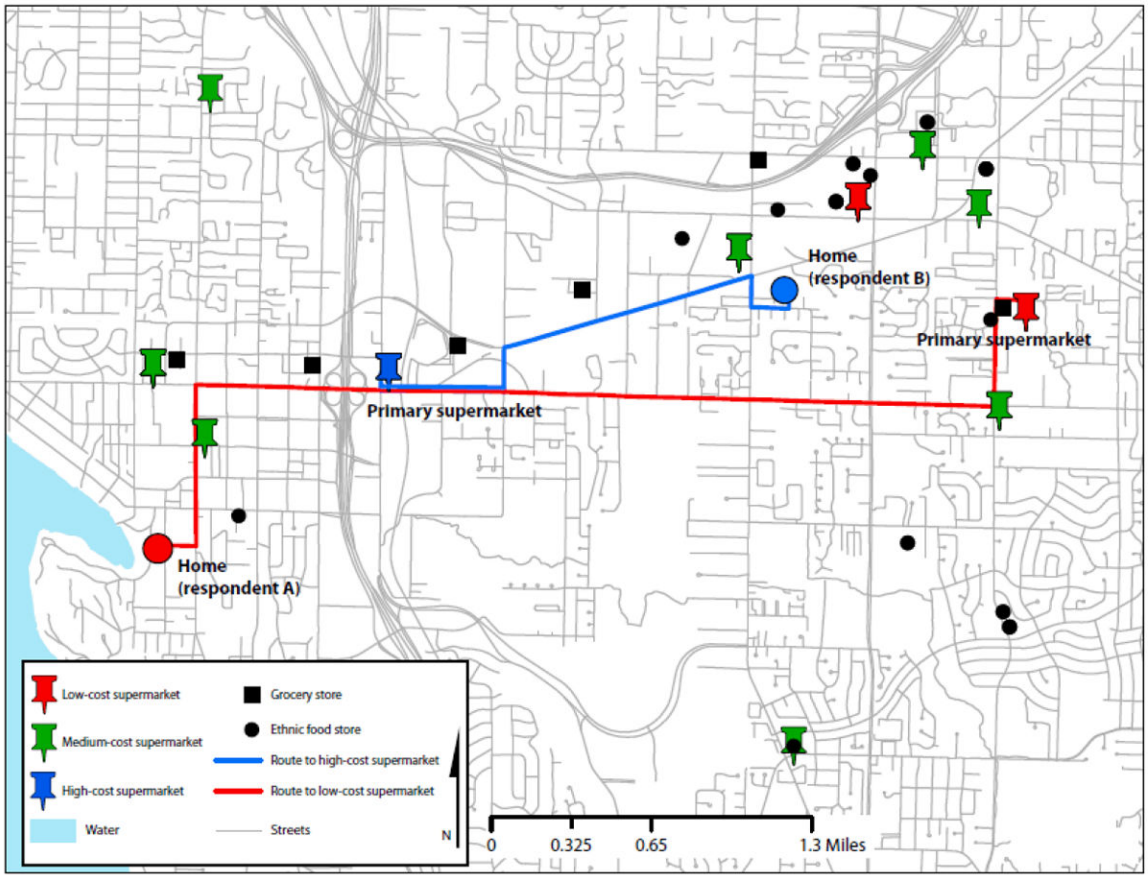

FIGURE 1.

Shortest network routes for 2 same-area residents who bypass proximal food stores to access their primary supermarket of choice: Seattle Obesity Study, 2008-2009.

Table 1

Fruit and vegetable consumption by key socio-demographic variables, distance traveled to primary supermarket and supermarket type: Seattle Obesity Study, 2008-2009

	Total N	Frequency of fruit and vegetable consumption per day Mean (SD)		Frequency of fruit and vegetable consumption per day Median (IQR)	
N	1386	4.18	(2.13)	3.86	(2.71,5.29)
Gender					
Men	521	3.89	(2.06)	3.49	(2.44,4.99)
Women	865	4.36	(2.15)	4.00	(2.93,5.43)
Age categories					
18-44yrs	363	4.03	(2.12)	3.78	(2.46,5.29)
45-64yrs	717	4.22	(2.22)	3.82	(2.71,5.35)
≥65yrs	306	4.29	(1.90)	4.00	(3.00,5.29)
Race/ethnicity					
Whites, Non-Hispanic	1135	4.18	(2.10)	3.82	(2.74,5.29)
Non whites	251	4.19	(2.23)	3.92	(2.57,5.29)
Annual household income					
<$50,000	556	4.03	(2.11)	3.64	(2.57,5.24)
≥$50,000	830	4.29	(2.13)	3.97	(2.85,5.35)
Education					
High school or less	245	3.79	(2.11)	3.29	(2.35,5.14)
Some college	357	3.87	(2.18)	3.43	(2.49,4.78)
College graduates or higher	784	4.45	(2.07)	4.19	(3.07,5.57)
Car Ownership					
Yes	1287	4.19	(2.10)	3.86	(2.72,5.29)
No	99	4.07	(2.45)	3.57	(2.29,5.43)
Distance traveled to the primary supermarket					
< 1mile	361	4.21	(2.06)	3.92	(2.86,5.29)
≥1 - <2miles	405	4.14	(2.01)	3.81	(2.77,5.29)
≥2 - <3miles	237	4.12	(2.06)	3.71	(2.57,5.56)
≥3miles	383	4.24	(2.35)	3.86	(2.70,5.26)
Supermarket type					

	Total N	Frequency of fruit and vegetable consumption per day Mean (SD)		Frequency of fruit and vegetable consumption per day Median (IQR)	
Low-cost	419	4.09	(2.09)	3.82	(2.60,5.16)
Medium-cost	806	4.10	(2.07)	3.71	(2.70,5.21)
High-cost	161	4.83	(2.36)	4.38	(3.29,6.00)

Abbreviations: Standard Deviation (SD), Interquartile range (IQR)

Table 2

Results of multivariate regression analyses assessing fruit and vegetable consumption according to demographic characteristics, distance to primary supermarket, and supermarket type: Seattle Obesity Study, 2008-2009

	Model 1			Model 2			Model 3		
	β	(95% CI)	p-value	β	(95% CI)	p-value	β	(95% CI)	p-value
SOCIOECONOMIC STATUS									
Annual household income									
< $50,000	Ref			Ref			Ref		
≥ $50,000	**0.27**	**(0.02, 0.51)**	**0.033**	0.06	(-0.19, 0.31)	0.637	0.06	(-0.19, 0.31)	0.627
Education									
High school or less	Ref			Ref			Ref		
Some college	0.14	(-0.21, 0.48)	0.430	0.12	(-0.22, 0.46)	0.490	0.12	(-0.22, 0.46)	0.479
College graduates or higher	**0.72**	**(0.41, 1.03)**	<**0.001**	**0.63**	**(0.30, 0.96)**	<**0.001**	**0.63**	**(0.30, 0.96)**	<**0.001**
DISTANCE TO STORES									
Primary Supermarket									
< 1 mile	Ref							Ref	
≥1 - <2 miles	-0.07	(-0.36, 0.22)	0.648				-0.02	(-0.30, 0.27)	0.917
≥2 - <3 miles	-0.09	(-0.42, 0.25)	0.612				-0.05	(-0.38, 0.28)	0.771
≥3 miles	0.05	(-0.27, 0.37)	0.776				0.05	(-0.27, 0.37)	0.770
SUPERMARKET TYPE BY PRICE									
Supermarket type									
Low-cost	Ref			Ref			Ref		
Medium-cost	0.04	(-0.21, 0.29)	0.733	-0.02	(-0.27, 0.23)	0.866	-0.01	(-0.26, 0.24)	0.934
High-cost	**0.76**	**(0.33, 1.19)**	<**0.001**	**0.56**	**(0.10, 1.01)**	**0.017**	**0.55**	**(0.09, 1.01)**	**0.018**

Abbreviations: β is the mean difference in number of fruit and vegetable consumption between a particular category and the reference category, Confidence interval (CI), *P* is the p-value

Model Framework: Estimates are from a linear regression model with robust standard errors with the following adjustments:
Model 1: Adjusted for age, gender, race/ethnicity, household size, residential density and car ownership
Model 2: Model 1 adjustments + income + education + supermarket type
Model 3: Model 2 adjustments + distance to primary supermarket

Table 3

Distribution of respondents whose nearest supermarket was their primary food source, by sociodemographic characteristics, distance variables, and supermarket type: Seattle Obesity Study, 2008-2009

	Total	Those whose primary supermarket was their nearest supermarket		
	N	N	%	*P*
Gender				
Men	521	180	(34.5)	0.633
Women	865	288	(33.2)	
Age categories				
18-44yrs	363	116	(31.9)	
45-64yrs	717	251	(35.0)	0.576
≥65yrs	306	101	(33.0)	
Race/ethnicity				
Whites, Non-Hispanic	1135	401	(35.3)	0.009
Non whites	251	87	(26.6)	
Annual household income				
<$35,000	325	102	(31.4)	
$35,000 - <$50,000	231	79	(34.2)	0.581
≥$50,000	830	287	(34.5)	
Education				
High school or less	245	82	(33.4)	
Some college	357	126	(35.2)	0.775
College graduates or higher	784	260	(33.1)	
Car Owner				
Yes	1287	435	(33.8)	0.925
No	99	33	(33.3)	
Supermarket type				
Low-cost	419	107	(25.5)	
Medium-cost	806	312	(38.7)	<0.001
High-cost	161	49	(30.4)	

Abbreviations: *P* is the p-value assessing the omnibus association between unadjusted relationship between each demographic variable and binary outcome indicating those traveling further then their primary supermarket.