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Fast food restaurants and food stores: longitudinal associations with diet in young adults: The CARDIA Study

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Abstract

Background—A growing body of cross-sectional, small-sample research has led to policy strategies to reduce food deserts – neighborhoods with little or no access to healthy foods – by limiting fast food restaurants and small food stores and increasing access to supermarkets in low-income neighborhoods.

Methods—We used 15 years of longitudinal data from the Coronary Artery Risk Development in Young Adults (CARDIA) study, a cohort of U.S. young adults (n=5,115, 18–30 years at baseline), with linked time-varying geographic information system-derived food resource measures. Using repeated measures from four examination periods (n=15,854 person-exam observations) and conditional regression (conditioned on the individual), we modeled fast food consumption, diet quality, and meeting fruit and vegetable recommendations as a function of fast food chain, supermarket, or grocery store availability (counts per population) within 1 kilometer (km), 1–2.9km, 3–4.9km, and 5–8km of respondents' homes. Models were sex-stratified, controlled for individual sociodemographics and neighborhood poverty, and tested for interaction by individual-level income.

Results—Fast food consumption was related to fast food availability in low-income respondents, particularly within 1–2.9km of homes among men [coefficient (95% CI) up to: 0.34 (0.16, 0.51)]. Greater supermarket availability was generally unrelated to diet quality and fruit and vegetable intake and relationships between grocery store availability and diet outcomes were mixed.

Conclusions—Our findings provide some evidence for zoning restrictions on fast food restaurants within 3km of low-income residents, but suggest that increased access to food stores may require complementary or alternative strategies to promote dietary behavior change.

INTRODUCTION

Reducing "food deserts" – defined as neighborhoods with poor access to healthy foods – by improving access to food resources in disadvantaged areas is a major component of the White House Task Force on Childhood Obesity[1] and is the objective of widespread policy initiatives across the United States (U.S.; e.g.,[2–3]). Such policies stem from limited evidence

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that food resources are related to obesity and are inequitably allocated across neighborhoods with varying wealth.[4–5] Implicit in these policy initiatives is that reduced access to fast food and increased access to supermarkets will translate into improvements in diet behavior and health.

However, evidence that food resources influence diet or obesity is mixed (e.g.,[4, 6–8]) and almost exclusively cross-sectional. Businesses locate in areas with the highest expected demand, and households locate according to affordability and other factors which may vary systematically with food resources and health-related behaviors. By addressing such factors, longitudinal studies can better estimate how food resources influence diet.[9] Additionally, there is no empirical evidence to guide the neighborhood areas in which food environment improvements should occur. Prior research examines food resources within a wide range of areas surrounding each home (e.g., [10–116, 12]), with few comparisons of how diet or health is related to food resources within varying degrees of proximity.[7, 11] Furthermore, diet decisions may be influenced by more proximate food resources for low-income individuals, who may have limited transportation options, and for fast food restaurants, which may involve more impulsive trips.[13]

Using longitudinal data on diet behavior and spatially linked neighborhood food resources in a large, biracial, adult cohort, we estimate the influence of neighborhood supermarket and grocery store availability on diet quality and consumption of fruit and vegetables, which are specifically targeted by policy initiatives. We also estimate the influence of fast food availability on fast food consumption – a process assumed but not demonstrated[7, 13] to underlie more commonly reported relationships between fast food availability and obesity[14–16] – and assess whether these relationships vary by individual-level income.

METHODS

Study Population and Data Sources

The Coronary Artery Risk Development in Young Adults (CARDIA) Study is a population-based prospective study of the determinants and evolution of cardiovascular risk factors among young adults. At baseline (1985–6), 5,115 eligible subjects, aged 18–30 years, were enrolled with balance according to race, gender, education (≤ and >high school) and age (18–24 and 25–30 years) from the populations of Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. Specific recruitment procedures were described elsewhere.[17] Follow-up examinations conducted in 1987–1988 (Year 2), 1990–1991 (Year 5), 1992–1993 (year 7), 1995–1996 (year 10), and 2000–2001 (year 15) had retention rates of 90%, 86%, 81%, 79%, and 74% of the surviving cohort, respectively.

Using a Geographic Information System (GIS), we linked time-varying, neighborhood-level food resource and U.S. Census data to CARDIA respondent residential locations in exam years 0, 7, 10, and 15 from geocoded home addresses. Among the 5115 participants at baseline, 48.2, 68.8, and 33.0% moved residential locations between years 0 and 7, 7 and 10, and 10 and 15, respectively.

Availability of neighborhood food resources

Fast-food chain restaurants, supermarkets (large grocery stores such as Kroger or Safeway), and smaller grocery stores were obtained from Dun and Bradstreet, a commercial dataset of U.S. business records. Food resources corresponding to each CARDIA exam period were extracted and classified according to 8-digit Standard Industrial Classification codes (Appendix Table e1). Eight-digit codes were not available for 1985–86, so year 0 food stores were classified using 4-digit codes and textual queries designed for consistency with other exam years. Counts of each type of food resource were calculated within 1, 3, 5, and

8.05 kilometers (km) of each respondent's residential location (Euclidean buffers), with the intent of capturing resources accessible by walking or by car. Specifically, 25% of all trips are less than 1.61 km (75% of these are by car), 62% of "social/recreational" trips are within 8.05 km,[18] and 72% of walking trips are under 1 km[19] (approximately a 15 minute walk). To test differences in how individual diet is related to food resources within varying distances, we examined food resources contained in concentric areas within 1 km, 1–2.9, 3–4.9, and 5–8.05 km of each respondent's residence (Figure 1).

Within each concentric area, we calculated fast food restaurant and grocery store counts per 10,000 population and, due to a smaller number of supermarkets, supermarket counts per 100,000 population. Population-scaled measures help to separate food resource availability from density of development, which is independently related to behavior[20–22] and other neighborhood characteristics.[23] Population within each area was derived from U.S. Census block-group population count, weighted according to the proportion of block-group area within each neighborhood buffer. While correlations of food resource availability among concentric areas were strong for food stores (up to 0.42 and 0.64 for supermarket and grocery store availability, respectively; ranged from −0.02 to 0.22 for fast food restaurants), examination of concentric areas allowed us to formally test associations across areas within the same model. Study conclusions were similar using 1, 3, 5, and 8 km buffers in separate models (reported in Appendix Tables e6–e8).

Diet measures

Frequency of chain fast food consumption was ascertained at each exam year. Participants were asked "How many times in a week or month do you eat breakfast, lunch or dinner in a place such as McDonald's, Burger King, Wendy's, Arby's, Pizza Hut, or Kentucky Fried Chicken?" Questions were open ended, but calculated to reflect a per-week consumption frequency.

Fruit and vegetable intake and overall diet quality was ascertained from an interviewer-administered, quantitative diet history of foods consumed over the past month and a questionnaire on usual dietary practices. Calculation of nutrient and energy intakes and validation of the CARDIA Diet History are described elsewhere.[24–26] Diet quality was measured using the Diet Quality Index (DQI),[27] which quantifies adherence to the 2005 Dietary Guidelines for Americans;[28] Appendix Table e1 describes scoring criteria. Briefly, the DQI incorporates adherence to recommendations for nutrients, food groups, and broader health messages (diversity, moderation, and minimization of added sugars), each assigned scores ranging from 0 to 10 which were summed for a maximum score of 100. Higher values reflect healthier diets. Adherence to fruit and vegetable recommendations, a common marker of healthy dietary patterns,[12] was derived from DQI components. This dichotomous measure also addressed highly skewed fruit and vegetable intakes and variation in recommended servings by sex and total energy intake.[29–30]

Control variables

Individual-level baseline characteristics included age (grand mean centered), race (white, black), and study center. Education (≤high school, some college, college graduate) at Year 7, after most individuals attained their highest education level, was examined as a time-constant variable; Year 0 education was used if Year 7 education was missing. Time-varying individual-level characteristics included income (continuous), marital status (married, not married), and children or stepchildren ≤18 years living in the household (any, none). Income was not collected in year 0 or 2, so the closest measurement (year 5) was analyzed; each year was inflated to 2001 U.S. dollars using the Consumer Price Index. Missing income (n=897 observations; 5.6%) was imputed based on individual-level age, race, sex, education, and study center; and residence within or outside of an urbanized area, census tract-level median household income, and county-level cost of living index.

Because neighborhood socioeconomic status correlated with food resource availability in prior research[4] and is independently related to diet,[31] we controlled for percent of persons <150% of federal poverty level (1.5*federal poverty level[32]) within the respondent's census tract of residence at the time of examination. Spearman correlations with neighborhood poverty were 0.40 for grocery stores within <1km and 1–2.3km, but otherwise smaller than ±0.15; associations adjusted and unadjusted for neighborhood poverty were similar.

Statistical Analysis

Effects of food resource availability on corresponding diet measures throughout young to middle adulthood were estimated in a series of sex-stratified longitudinal models. We focused on the most theoretically direct relationships: fast food consumption in relation to fast food availability, and diet quality and fruit and vegetable consumption in relation to supermarket and grocery store availability. Most interactions between sex and each independent variable were significant (Wald p<0.10) so models were sex-stratified.

We used fixed effect longitudinal models, which exploit the repeated measures of environment and diet in the CARDIA study by conditioning on each individual, thereby analyzing variation observed within person, over time. In this way, fixed effect models control for time-constant unmeasured variables (e.g., diet preferences that remain constant over time).[34–36] In essence, each individual serves as his/her own control in fixed effect models. In contrast, random effects models (random person-level intercept) analyze variation both within and between individuals; they do not control for possible correlation between observed and unmeasured characteristics and are therefore more comparable to cross-sectional associations reported in prior research. The Hausman specification test indicated systematic bias with respect to the independent variables (p<0.001), so we report the more robust fixed effects estimates; corresponding random effects estimates are reported in Appendix Tables e6–e8.

Models were fit using Stata 10.1 xt longitudinal functions (xtpoisson for fast food frequency, xtreg for diet quality, xtlogit for meeting fruit and vegetable recommendations), using the "fe" option.[37] As described elsewhere,[38] we treat neighborhood poverty as an individual-level exposure.

Natural-log transformation of food resource variables linearized relationships. All models controlled for time-varying age, income, marital status, children, and neighborhood poverty; because fixed effects models rely on within-person variation, coefficients for time-constant variables (study center, education, race, sex) are not estimated. To test the hypothesis that food resources within a shorter distance from home influence diet in low-income groups, we tested interactions by individual-level income (3 categories with adequate counts in whites and blacks: low, <$20,000; medium, $20,000–89,900; and high, ≥$90,000); income-specific associations calculated from estimated main effect and income interaction coefficients are presented for models containing significant (Wald p<0.10) income interactions. Due to unstable estimates, income interactions are not reported for fruit and vegetable recommendations. P-values for income interactions and Bonferroni-corrected comparison of estimates for food resources within different concentric areas are reported in Appendix Tables e4 and e5.

Due to differences in diet measures collected across CARDIA exam year, fast food availability in relation to fast food consumption (fast food model) was examined using exam years 7, 10, and 15; and supermarkets and grocery stores in relation to diet quality and fruit

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and vegetable intake (food store models) were examined using exam years 0 and 7. Study retention and exclusions are presented in Figure 2; analytical samples included 10,975 (fast food model) and 8,652 (food stores models) person-exam observations. Food resource data were complete for all observations, so exclusion was unrelated to the study exposures. Additionally, our fixed effects models may mitigate selection bias (attrition and missing data) related to unobserved fixed individual-level characteristics.

RESULTS

Men and women differed on all individual-level characteristics except age (Table 1); in particular, females reported healthier diets than males. Appendix Table e3 reports neighborhood characteristics.

The relationship between neighborhood fast food restaurant availability and individual fast food consumption differed dramatically by income level (Figure 3; interaction $p<0.05$, see Appendix Table e4 for details). In low-income men, a 1% increase in fast food availability within <1 km and 1–2.9 km was related to a 0.13% and 0.34% increase in fast food consumption frequency, respectively; fast food availability within more distant areas was unrelated to fast food consumption. Associations between neighborhood fast food availability and individual consumption were not significant in low-income women, variably significant but weak in middle-income respondents, and inconsistent with significant counterintuitive associations in high-income respondents.

Neighborhood supermarket and grocery store availability were generally unrelated to diet quality and meeting fruit and vegetable recommendations (Table 2), with similar associations across income levels (interaction $p>0.10$). Supermarket availability within 1–2.9 km was associated with greater adherence to fruit and vegetable recommendations in men, but this estimate did not significantly differ from estimates for other concentric areas. Greater grocery store availability within 1–2.9 km was related to significantly lower diet quality in high-income women, but higher diet quality in low-income men (Figure 4; interaction $p<0.10$, see Appendix Table e5 for details). Relationships between diet quality and grocery store availability also varied in magnitude and direction across concentric areas.

DISCUSSION

Using a large, diverse, prospective cohort, we conducted the first longitudinal study to estimate how diet is influenced by food resource availability within varying distances from homes. We found evidence that low-income men may be sensitive to fast food availability within shorter distances from home, but findings for women and higher income men were mixed. Supermarket and grocery store availability were generally unrelated to diet. These findings have critical implications for existing and proposed policies aimed at improving access to healthy foods.

Evidence that food resource availability influences diet

Numerous obesity prevention policies (e.g.,[1–2]) target fast food restaurants and food stores, with the assumption that they influence diet behaviors.

Fast food chain restaurants—We found some support for policies targeting fast food restaurants. Specifically, we add to scarce longitudinal evidence that greater availability of chain fast food restaurants may promote greater fast food consumption in low-income groups. These findings are consistent with prior longitudinal research in new mothers[39] and evidence of greater fast food availability[4–5] in lower income groups.

Fast food consumption was most strongly related to fast food availability close to homes in low-income men, who may be less likely to own a car, thereby limiting mobility and enhancing reliance on the immediate neighborhood area.[15] Due to perceived cost or other barriers,[40] low-income individuals may be more sensitive to cues related to the presence of fast food restaurants.[13] Indeed, in a similar study population, those with low-income or education were more likely to consume fast food within a mile of their home.[41]

Supermarkets—Most policies targeting food deserts focus on adding supermarkets to low-income areas (e.g., [1, 5, 42]), with the expectation of increased consumption of healthy foods such as fruits and vegetables.[43] In our longitudinal study, neighborhood supermarket availability was generally unrelated to both adherence to fruit and vegetable recommendations and overall diet quality (reflecting compliance with the Dietary Guidelines for Americans[28]).

Findings from our longitudinal analysis do not replicate findings from prior studies using similar measures. Analyzing the same data using random effects models, which rely on between-person variation and are thus more comparable with cross-sectional analysis, yielded associations consistent with published, largely cross-sectional research (e.g.,[4, 44–45]) (Appendix Tables e6–e8). Our findings suggest that evidence of the health benefits of nearby supermarkets may reflect unmeasured respondent characteristics related to both diet behaviors and selection of certain types of neighborhoods, or placement of supermarkets in areas with the greatest demand.

Furthermore, our longitudinal findings are consistent with one of few quasi-experimental studies, in which changes in fruit and vegetable consumption following the opening of a supermarket-type store in the United Kingdom (UK) were similar to a control neighborhood.[46] An Institute of Medicine-National Academy of Science workshop[47] and more recent USDA research[48] also suggest that proximity to supermarkets may not be an important influence on diet, but experimental and quasi-experimental studies are needed in U.S. settings.

Moving beyond food resource availability

Another critical aspect of recent food environments policies is their focus on the availability (presence or quantity) of specific types of food stores or restaurants. Correspondingly, our study estimated how availability of chain fast food restaurants, supermarkets, and smaller grocery stores influences diet. However, variation in the types and quality of the items sold within each type of food resource may have contributed to inconsistent or unexpected findings.

Notably, dramatic variation in how availability of smaller grocery stores is related to diet behaviors mirror contradictory conceptualizations of grocery stores as similar to supermarkets[6, 49] or as less affordable, less healthy food stores.[50–51] Our finding that grocery store availability was related to better diet quality only in low-income men is consistent with characterization of grocery stores as sources of healthy food for low-income groups who may lack access to other food stores.[10] In contrast, lower diet quality associated with greater grocery store availability nearby high income women may reflect the role of grocery stores as sources of unhealthy food among those who purchase the bulk of their food at supermarkets.[11]

Likewise, the vast array of healthy and unhealthy foods offered at supermarkets may contribute to our finding that supermarket availability was unrelated to overall diet quality. The unexpected inverse relationship between fast food restaurant availability and individual fast food consumption among high income women could reflect reporting bias or dietary restraint,[52] but could also reflect their greater use of non-traditional fast food restaurants such as burrito or sandwich shops that were not elicited in the CARDIA fast food consumption measure.

Overall, classification of food stores and restaurants into "healthy" or "unhealthy" according to mode of service (fast food or sit-down) or size (supermarket versus grocery store) may provide little understanding of how the food environment impacts diet and may overlook innovative policy solutions. Indeed, distinctions between fast food and sit-down restaurants on the basis of healthfulness of foods served (portion size, calorie content) or inequitable distribution among wealthy and poor neighborhoods appear to be unfounded.[2] Alternative or complimentary policies include subsidies to small grocery stores for increasing access to specific foods such as produce and reduced fat milk,[5] although corresponding research is similarly challenging without meaningful classifications of "healthy" or "unhealthy" food items. Cummins and collegues report the greatest improvements in fruit and vegetable intake among those who adopted a new supermarket as their main food store, suggesting that promotion of existing, new, or improved food resources is an important component of successful policies. Furthermore, selection of foods from the surrounding food environment occurs within the macro-level context of food production and pricing driven by the food industry and government regulation and micro-level context of household financial resources and time constraints. For example, subsidizing the production of fruits and vegetables may reduce prices, encourage smaller stores to stock fresh produce, and ultimately make healthy diet choices more available and affordable to low-income households. Similarly, local food resources may have broad health[43] and economic benefits regardless of their impact on diet. Food environment policies should be created and evaluated within this complex web of influences.

Study limitations

The primary limitation of our study is that our food resource database may have contained error and did not measure availability of specific foods. Coding differences for Year 0 food resource data may have resulted in differential identification and misclassification of supermarkets and grocery stores in years 0 versus 7, although error is unlikely to vary systematically with diet behaviors. Our fast food restaurant availability measure excluded non-chain restaurants which may serve similar types of foods, but was consistent with the CARDIA individual-level fast food consumption measure. Because chain fast food restaurant availability was not available in year 0, we were not able to replicate our diet quality analysis with fast food availability.

Inconsistent associations across concentric areas may have resulted from several geographic considerations. While our analyses address variations in resources with population density and wealth, our findings may reflect geographic clustering of retail land uses at varying distances from residential areas. Diet may be differentially related to food resources at varying proximities according to population density, however the CARDIA population resides largely in metropolitan areas. We did not study where food was purchased, or the role of food resources around the workplace. Additionally, capturing individual perceptions of neighborhood boundaries[53] is not feasible in a large-scale longitudinal study, but neighborhood buffer zones allowed us to explicitly measure proximity. Our concentric buffer areas may be more sensitive to geocoding inaccuracies, but locational error of other resources in the Dun and Bradstreet database were far less (average 35 meters) than the kilometer distances used in this study.[54]

Lastly, car ownership may influence relevant proximity to resources but was not collected in the CARDIA study. Inconsistences may also reflect chance findings, so replication in other longitudinal study populations is needed. Nonetheless, our data provided comparable, objective, and time-varying data for a large, diverse sample of young adults residing throughout the U.S. and followed into middle age.

Conclusion

By promoting greater access to supermarkets, several U.S. policies aim to improve diets through provision of affordable healthy foods, particularly fresh produce in underserved areas.[1] Our findings do not support this initiative in young- to middle-aged adults. Rather, they suggest that adding neighborhood supermarkets may have little benefit to overall diet quality across the income spectrum and that other policy options such as targeting specific foods or shifting food costs[55] (subsidization or taxation)[2] should be further considered. We found evidence that reducing availability of fast food chain restaurants within 3 km of low-income residents may yield reductions in fast food consumption. While these policy implications should be confirmed with further research and explored in youth and older adults, our findings support continued innovations in the measurement and modification of the neighborhood food environment to most effectively promote healthy diets and prevent obesity, an essential component for clinicians to guide patients in the optimal use of neighborhood resources.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

1. [Accessed July 7, 2010] Let's Move. Accessing healthy & affordable food. http://letsmove.gov/accessing/index.html
2. Sturm R, Cohen DA. Zoning For Health? The Year-Old Ban On New Fast-Food Restaurants In South LA. Health Aff (Millwood). 2009 Oct 6.
3. New York Economic Development Corp. [Accessed July 7, 2010] New York City industrial development agency approves incentives for first two supermarkets under the fresh program. 2010 February 9. http://www.nycedc.com/PressRoom/PressReleases/Pages/IDAApprovesIncentivesforSupermarkets.aspx
4. Larson NI, Story MT, Nelson MC. Neighborhood environments: disparities in access to healthy foods in the U.S. Am J Prev Med. 2009 Jan; 36(1):74–81. [PubMed: 18977112]
5. The public health effects of food deserts: workshop summary. Washington, DC: 2009. Institute of Medicine, National Research Council.

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6. Gary-Webb TL, Baptiste-Roberts K, Pham L, et al. Neighborhood and weight-related health behaviors in the Look AHEAD (Action for Health in Diabetes) study. BMC Public Health. Jun 4.10(1):312. [PubMed: 20525373]
7. Jeffery RW, Baxter J, McGuire M, Linde J. Are fast food restaurants an environmental risk factor for obesity? Int J Behav Nutr Phys Act. 2006; 3:2. [PubMed: 16436207]
8. Auchincloss AH, Diez Roux AV, Brown DG, Erdmann CA, Bertoni AG. Neighborhood resources for physical activity and healthy foods and their association with insulin resistance. Epidemiology. 2008 Jan; 19(1):146–157. [PubMed: 18091002]
9. Boone-Heinonen, J.; Gordon-Larsen, P.; Guilkey, D.; Jacobs, DR.; Popkin, BM. Environment and physical activity dynamics: the role of residential self-selection. Psychology of Sport and Exercise. 2010. in press; available at: http://dx.doi.org/10.1016/j.psychsport.2009.1009.1003
10. 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. 2008 Apr; 11(4):413–420. [PubMed: 17617930]
11. Rose D, Hutchinson PL, Bodor JN, et al. Neighborhood food environments and Body Mass Index: the importance of in-store contents. Am J Prev Med. 2009 Sep; 37(3):214–219. [PubMed: 19666158]
12. Morland K, Wing S, Diez Roux A. The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. Am J Public Health. 2002 Nov; 92(11):1761–1767. [PubMed: 12406805]
13. Paquet C, Daniel M, Knauper B, Gauvin L, Kestens Y, Dube L. Interactive effects of reward sensitivity and residential fast-food restaurant exposure on fast-food consumption. Am J Clin Nutr. Mar; 91(3):771–776. [PubMed: 20089726]
14. Bodor JN, Rice JC, Farley TA, Swalm CM, Rose D. The Association between Obesity and Urban Food Environments. J Urban Health. May 11.
15. Inagami S, Cohen DA, Brown AF, Asch SM. Body mass index, neighborhood fast food and restaurant concentration, and car ownership. J Urban Health. 2009 Sep; 86(5):683–695. [PubMed: 19533365]
16. Li F, Harmer P, Cardinal BJ, Bosworth M, Johnson-Shelton D. Obesity and the built environment: does the density of neighborhood fast-food outlets matter? Am J Health Promot. 2009 Jan–Feb; 23(3):203–209. [PubMed: 19149426]
17. Hughes GH, Cutter G, Donahue R, et al. Recruitment in the Coronary Artery Disease Risk Development in Young Adults (Cardia) Study. Control Clin Trials. 1987 Dec; 8(4 Suppl):68S–73S. [PubMed: 3440391]
18. Nationwide Personal Transportation Survey. U.S. Department of Transportation; 1995. Federal Highway Administration.
19. Antonakos CL. Nonmotor travel in the 1990 National Personal Transportation Survey. Transportation Res Rec. 1995; 1502:75–82.
20. Boone-Heinonen J, Evenson KR, Song Y, Gordon-Larsen P. Built and socioeconomic environments: patterning and associations with physical activity in U.S. adolescents. Int J Behav Nutr Phys Act. 2010; 7:45. [PubMed: 20487564]
21. Cervero R, Kockelman K. Travel demand and the 3Ds: Density, diversity, and design. Transportation Research Part D-Transport and Environment. 1997 Sep; 2(3):199–219.
22. Kestens Y, Daniel M. Social inequalities in food exposure around schools in an urban area. Am J Prev Med. 2010 Jul; 39(1):33–40. [PubMed: 20537844]
23. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P. Food Deserts: are we looking in the right places? forthcoming. 2010
24. Liu K, Slattery M, Jacobs D, et al. A study of the reliability and comparative validity of the CARDIA dietary history. Ethnicity & Disease. 1994; 4(1):15–27. [PubMed: 7742729]
25. McDonald A, Van Horn L, Slattery M, et al. The CARDIA dietary history: development, implementation, and evaluation. J Am Diet Assoc. 1991 Sep; 91(9):1104–1112. [PubMed: 1918764]

26. Slattery ML, McDonald A, Bild DE, et al. Associations of body fat and its distribution with dietary intake, physical activity, alcohol, and smoking in blacks and whites. Am J Clin Nutr. 1992 May; 55(5):943–949. [PubMed: 1570801]

27. Zamora D, Penny Gordon-Larsen, David Jacobs, Barry M Popkin. Diet quality and weight gain among Black and White young adults: the CARDIA study. American Journal of Clinical Nutrition. in press.

28. Dietary Guidelines for Americans, 2005. 6th ed. Washington, DC: Government Printing Office; 2005.

29. U.S. Department of Agriculture. Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010. 2010. Available at: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm

30. Dietary Guidelines for Americans 2005. Washington, DC: 2005 January. U.S. Department of Health and Human Services, U.S. Department of Agriculture. 2005

31. Dubowitz T, Heron M, Bird CE, et al. Neighborhood socioeconomic status and fruit and vegetable intake among whites, blacks, and Mexican Americans in the United States. Am J Clin Nutr. 2008 Jun; 87(6):1883–1891. [PubMed: 18541581]

32. U.S. Census Bureau. [Accessed 3/19/2010] How the Census Bureau Measures Poverty. 9/29/2009. 2010. http://www.census.gov/hhes/www/poverty/povdef.html

33. Boone-Heinonen J, Gordon-Larsen P, Guilkey D, Jacobs DR, Popkin BM. Environment and physical activity dynamics: the role of residential self-selection. Psychology of Sport and Exercise. 2009 in press.

34. Boone-Heinonen J, Diez Roux A, Kiefe CI, Lewis CE, Guilkey D, Gordon-Larsen P. Neighborhood socioeconomic status predictors of physical activity through young to middle adulthood: The CARDIA Study. Soc Sci Med. in press.

35. Boone-Heinonen J, Gordon-Larsen P, Guilkey D, Jacobs DR, Popkin BM. Environment and physical activity dynamics: the role of residential self-selection. Psych Sport Exercise. 2011; 12:54–60.

36. Boone-Heinonen J, Guilkey DK, Evenson KR, Gordon-Larsen P. Residential self-selection bias in the estimation of built environment effects on physical activity between adolescence and young adulthood. Int J Behav Nutr Phys Act. 2010; 7:70. [PubMed: 20920341]

37. StataCorp. Longitudinal Panel Data manual, Stata Statistical Software, Release 9. College Station, TX: StataCorp LP; 2005.

38. Boone-Heinonen J, Diez Roux A, Kiefe CI, Lewis CE, Guilkey D, Gordon-Larsen P. Neighborhood socioeconomic status predictors of physical activity through young to middle adulthood: The CARDIA Study. under review. 2009

39. Currie, J.; DellaVinga, S.; Moretti, E.; Pathania, V. NBER Working Paper 14721: The effect of fast food restaurants on obesity. Cambridge: National Bureau of Economic Research; 2009. available at: http://www.nber.org/papers/w14721

40. Dammann KW, Smith C. Factors affecting low-income women's food choices and the perceived impact of dietary intake and socioeconomic status on their health and weight. J Nutr Educ Behav. 2009 Jul–Aug; 41(4):242–253. [PubMed: 19508929]

41. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR, Franco M. Fast-food consumption, diet quality, and neighborhood exposure to fast food: the multi-ethnic study of atherosclerosis. Am J Epidemiol. 2009 Jul 1; 170(1):29–36. [PubMed: 19429879]

42. [Accessed July 7, 2010] The Food Trust. Pennsylvania Fresh Food Financing Initiative. http://www.thefoodtrust.org/php/programs/fffi.php

43. Cummins S, Petticrew M, Higgins C, Findlay A, Sparks L. Large scale food retailing as an intervention for diet and health: quasi-experimental evaluation of a natural experiment. J Epidemiol Community Health. 2005 Dec; 59(12):1035–1040. [PubMed: 16286490]

44. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Prev Med. 2004 Nov; 39(5):869–875. [PubMed: 15475018]

45. 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. 2008 Apr 15; 167(8):917–924. [PubMed: 18304960]

46. Cummins S, Petticrew M, Sparks L, Findlay A. Large scale food retail interventions and diet. BMJ. 2005 Mar 26; 330(7493):683–684. [PubMed: 15790619]
47. National Research Council. The Public Health Effects of Food Deserts: Workshop Summary. Washington DC: National Academy Press; 2009.
48. Ver Ploeg, M. Access to affordable, nutritious food is limited in "food deserts"; Amber Waves. 2010. p. 20-27.Available at: http://www.ers.usda.gov/AmberWaves/March10/Features/FoodDeserts.htm
49. Murakami K, Sasaki S, Takahashi Y, Uenishi K, the Japan Dietetic Students' Study for N. Biomarkers G. Neighbourhood food store availability in relation to 24 h urinary sodium and potassium excretion in young Japanese women. Br J Nutr. Apr 27.:1–8.
50. Block D, Kouba J. A comparison of the availability and affordability of a market basket in two communities in the Chicago area. Public Health Nutr. 2006 Oct; 9(7):837–845. [PubMed: 17010248]
51. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. Am J Prev Med. 2006 Jan; 30(1):38–44. [PubMed: 16414422]
52. Dykes J, Brunner EJ, Martikainen PT, Wardle J. Socioeconomic gradient in body size and obesity among women: the role of dietary restraint, disinhibition and hunger in the Whitehall II study. Int J Obes Relat Metab Disord. 2004 Feb; 28(2):262–268. [PubMed: 14647173]
53. Chaix B, Merlo J, Evans D, Leal C, Havard S. Neighbourhoods in eco-epidemiologic research: delimiting personal exposure areas. A response to Riva, Gauvin, Apparicio and Brodeur. Soc Sci Med. 2009 Nov; 69(9):1306–1310. [PubMed: 19692161]
54. Boone JE, Gordon-Larsen P, Stewart JD, Popkin BM. Validation of a GIS facilities database: quantification and implications of error. Ann Epidemiol. 2008 May; 18(5):371–377. [PubMed: 18261922]
55. Duffey KJ, Gordon-Larsen P, Shikany JM, Guilkey D, Jacobs DR Jr, Popkin BM. Food price and diet and health outcomes: 20 years of the CARDIA Study. Arch Intern Med. 2010 Mar 8; 170(5): 420–426. [PubMed: 20212177]

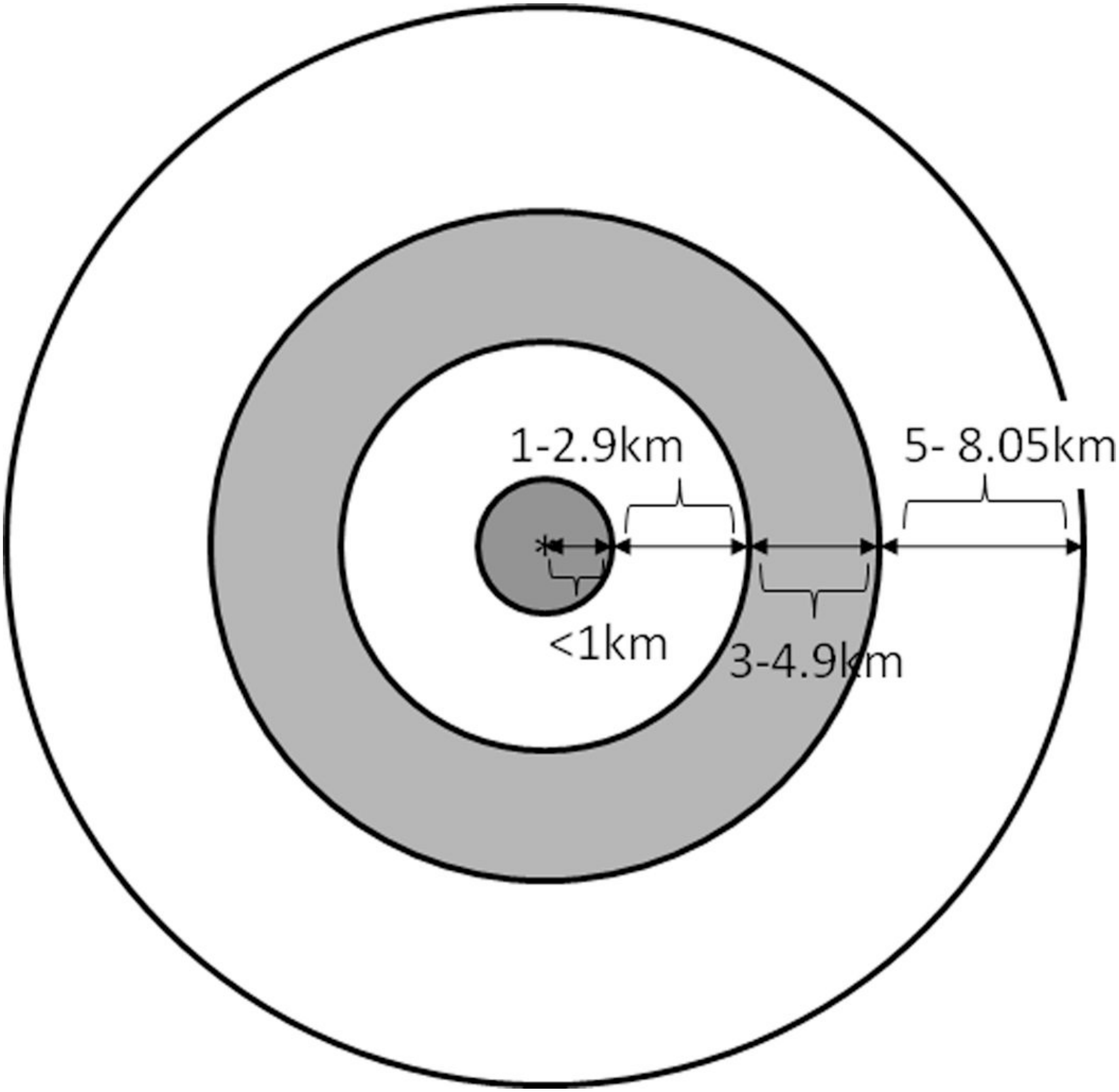

Figure 1.
Concentric areas in which food resource availability was measured.
*Asterisk indicates location of respondent residence. Food resource availability was measured within each concentric area: within 1km, between 1 and 3 km, between 3 and 5 km, and between 5 and 8.05 km.

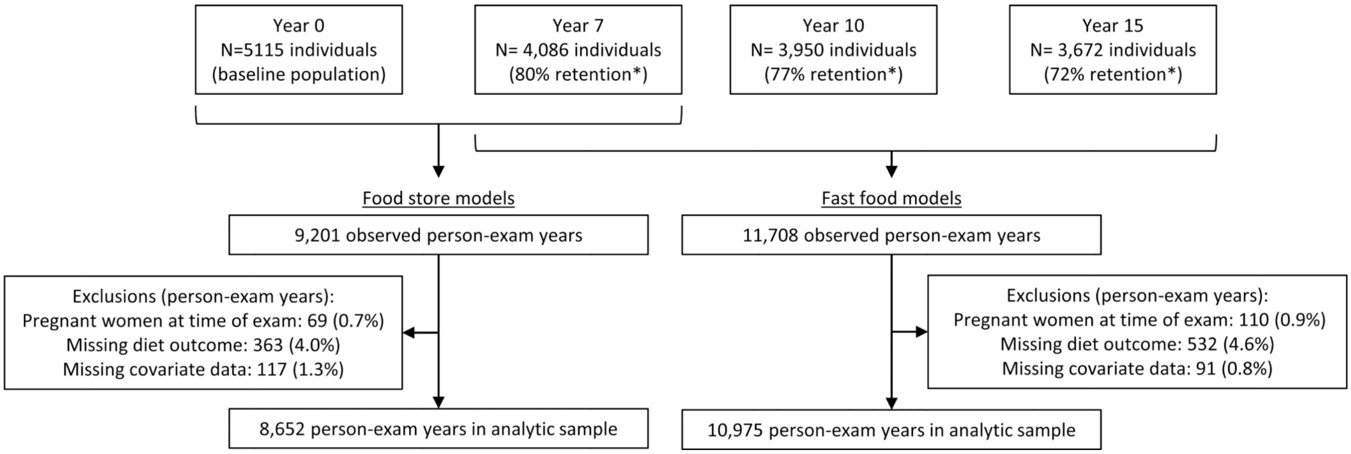

Figure 2.
Summary of study retention and exclusions
Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2000)
*Retention incorporates loss to follow-up and mortality

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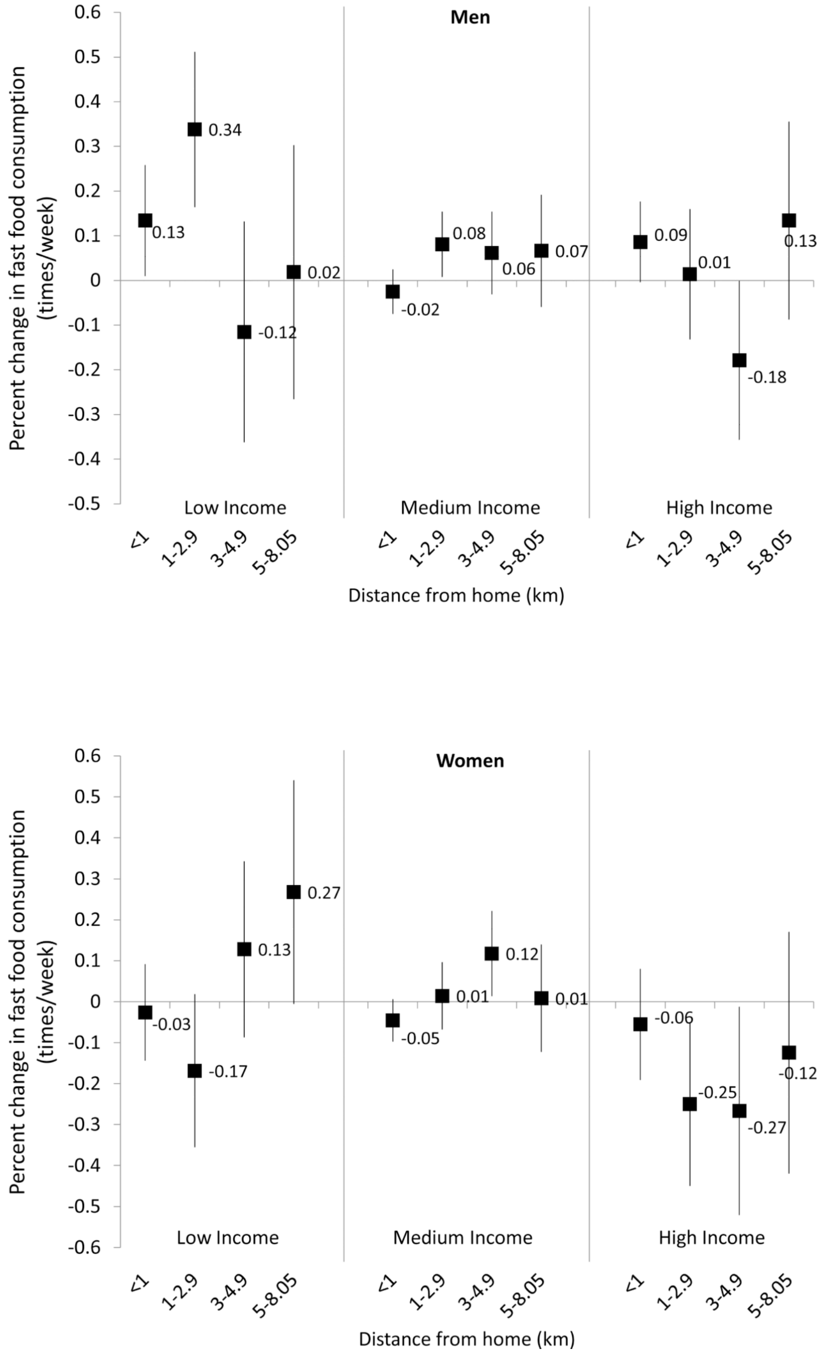

Figure 3.

Estimated effectsa of fast food availability within concentric areas around residential locations on weekly frequency of fast food consumption, by individual-level income

[a]Estimated using fixed effects Poisson regression modeling fast food consumption (times per week) as a function of fast food restaurant availability (fast food restaurant counts per 10,000 population) in the areas within 1k and between 1 and 3k, 3 and 5k, and 5 and 8k of each Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2000) respondent's home, adjusting for time-varying age, income, marital status, children in household and percent of persons below 150% of federal poverty level; race, education, and study center are time invariant and therefore omitted from fixed effects models. Income-

specific estimates were obtained from models containing income interactions with fast food restaurant availability within each neighborhood area. Coefficients can be interpreted as the percent change in fast food consumption expected from a 1% change in fast food restaurant availability. Error bars represent 95% confidence intervals.

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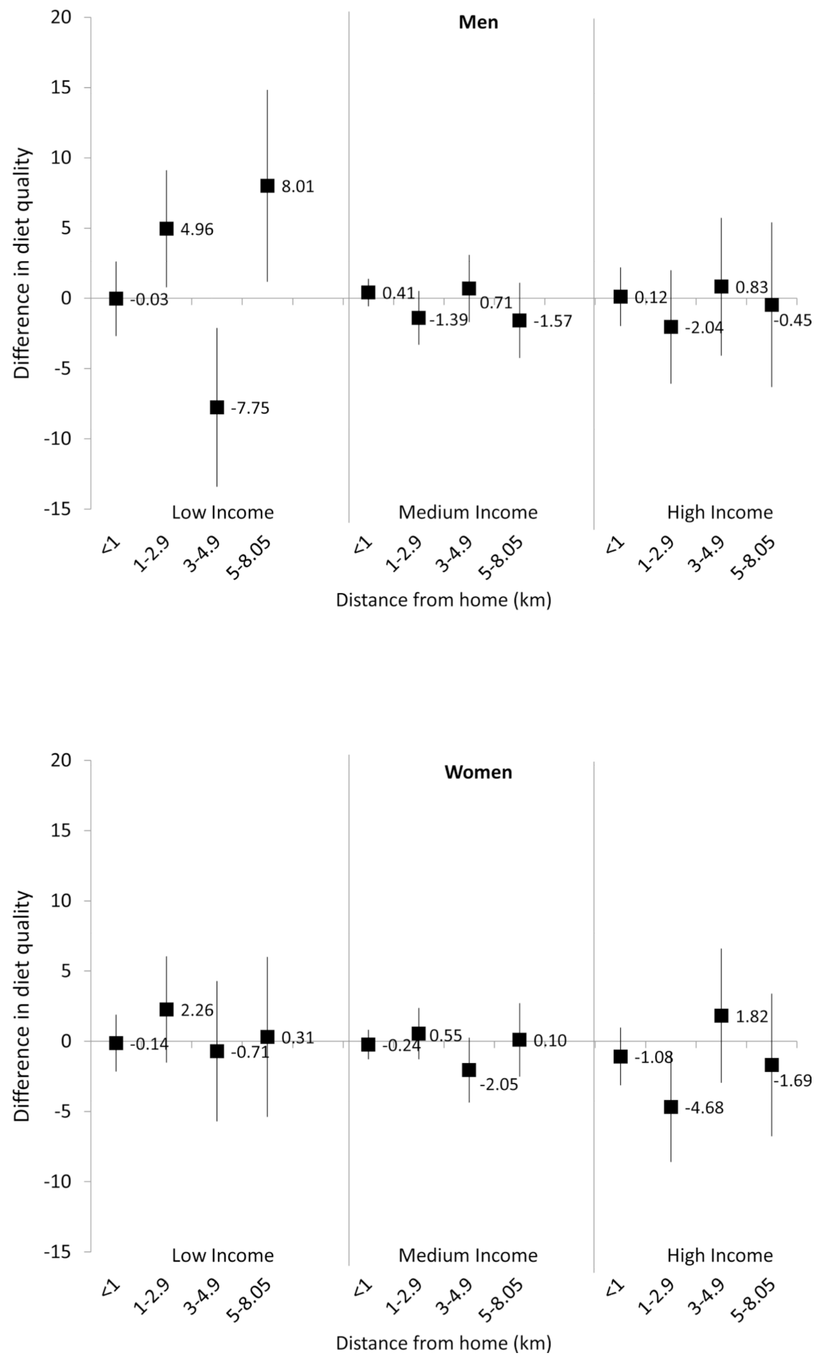

Figure 4.

Estimated effectsa of grocery store availability within concentric areas around residential locations on diet quality, by individual-level income

[a]Estimated using fixed effects linear regression modeling diet quality index as a function of grocery store availability (grocery store counts per 10,000 population) in the areas within 1k and between 1 and 3k, 3 and 5k, and 5 and 8k of each Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2000) respondent's home, adjusting for time-varying age, income, marital status, children in household and percent of persons below 150% of federal poverty level; race, education, and study center are time invariant and therefore omitted from fixed effects models. Income-specific estimates were obtained from

models containing income interactions with grocery store availability within each neighborhood area. Coefficients can be interpreted as change in DQI expected from a 1% change in grocery store density. Error bars represent 95% confidence intervals.

Table 1

Individual-level sample characteristics of the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985–2000, by sex[a] [mean/% (standard error)]

	Men (n=2,208)[b]	Women (n=2,671)[b]
White[b] (%)	51.0	47.1
Education[c] (%)		
≥College grad	33.9	35.2
Some college	8.2	10.6
≤HS	57.8	54.3
Married[b] (%)		
Never	73.0	65.8
Current	20.7	23.9
Former	6.3	10.4
Child(ren) in household[bd] (%)	16.8	35.7
Age[b] (mean)	24.8 (0.1)	24.9 (0.1)
Income, in $10,000[be] (mean)[e]	6.3 (0.1)	5.9 (0.1)
Fast food consumption, times/week[f] (mean)	2.1 (0.0)	1.6 (0.0)
Diet Quality Index[f] (mean)	46.5 (0.2)	53.0 (0.2)
Meets fruit and vegetable recommendations[f] (%)	5.6	8.7

[a]All variables significantly different by sex ($p<0.05$) except age

[b]At baseline (Year 0)

[c]Education attained by Year 7; imputed with education at Year 0 where missing

[d]Children or stepchildren living in household

[e]Inflated to reflect value of 2000 U.S. dollars

[f]Pooled over exam years in which diet behavior was measured (Fast food, Years 7, 10, 15; Diet quality and Fruit and vegetable consumption, Years 0 and 7)

Table 2

Estimated effects[a] of food stores within concentric areas around residential locations on diet quality and meeting fruit and vegetable intake recommendations [coefficient (95% CI)]

	Supermarkets		Grocery Stores[c]
Distance from residence	**Diet quality [coefficient (95% CI)]**	**Meets fruit & vegetable recommendations [OR (95% CI)]**	**Meets fruit & vegetable recommendations [OR (95% CI)]**
Men (n=3,921)[b]			
<1 km	−0.05 (−0.60, 0.50)	1.10 (0.81, 1.49)	1.01 (0.63, 1.62)
1 to 2.9 km	−0.38 (−1.19, 0.43)	**2.14 (1.19, 3.83)**	1.20 (0.45, 3.18)
3 to 4.9 km	−0.01 (−0.97, 0.95)	1.02 (0.53, 1.96)	1.05 (0.33, 3.35)
5 to 8 km	0.60 (−0.51, 1.71)	0.58 (0.29, 1.16)	0.48 (0.10, 2.23)
Women (n=4,731)[b]			
<1 km	−0.19 (−0.71, 0.32)	0.93 (0.78, 1.12)	0.98 (0.69, 1.38)
1 to 2.9 km	−0.25 (−1.05, 0.55)	0.80 (0.59, 1.08)	1.20 (0.65, 2.20)
3 to 4.9 km	−0.38 (−1.28, 0.53)	0.90 (0.64, 1.26)	0.45 (0.20, 1.02)
5 to 8 km	0.58 (−0.42, 1.58)	1.45 (0.97, 2.16)	1.12 (0.50, 2.54)

[a]Estimated using fixed effects linear (diet quality) or logistic (fruit and vegetable recommendations) regression modeling diet quality index or compliance with fruit and vegetable recommendations as a function of supermarket or grocery store density (supermarket counts per 100,000 population, or grocery store counts per 10,000 population) in the areas within 1k and between 1 and 3k, 3 and 5k, and 5 and 8k of each Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2000) respondent's home, adjusting for time-varying age, income, marital status, children in household and percent of persons below 150% of federal poverty level; race, education, and study center are time invariant and therefore omitted from fixed effects models. Coefficients can be interpreted as change in DQI expected from a 1% change in food store density; odds ratios can be interpreted as increased odds of meeting fruit and vegetable recommendations expected from a 1% change in food store density. Bold font indicates statistical significance ($p<0.05$). Model 1 estimates were not significantly different from each other within sex.

[b]Counts (n) indicate number of person-year observations.

[c]Estimated effects of grocery stores on diet quality varied significantly by individual-level income; income-specific estimates are reported in Figure 4.