

## HEALTH CARE REFORM

## Fast Food Restaurants and Food Stores

*Longitudinal Associations With Diet in Young to Middle-aged Adults: The CARDIA Study*

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**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 US young adults (aged 18-30 years at baseline) (n=5115), with linked time-varying geographic information system-derived food resource measures. Using repeated measures from 4 examination periods (n=15 854 person-examination observations) and conditional regression (conditioned on the individual), we modeled fast food consumption, diet quality, and adherence to fruit and vegetable recommendations as a function of fast food chain, supermarket, or grocery store availability (counts per population) within less than 1.00 km, 1.00 to 2.99 km, 3.00 to 4.99 km, and 5.00 to 8.05 km

of respondents' homes. Models were sex stratified, controlled for individual sociodemographic characteristics and neighborhood poverty, and tested for interaction by individual-level income.

**Results:** Fast food consumption was related to fast food availability among low-income respondents, particularly within 1.00 to 2.99 km of home among men (coefficient, 0.34; 95% confidence interval, 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.

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

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**R**EDUCING FOOD DESERTS—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<sup>1</sup> and is the objective of widespread policy initiatives across the United States.<sup>2,3</sup> Such policies stem from limited evidence that food resources are related to obesity and are inequitably allocated according to neighborhood wealth.<sup>4,5</sup> 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.

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However, evidence that food resources influence diet or obesity is mixed<sup>4,6-8</sup> 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.<sup>9</sup> In addition, 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,<sup>6,10-12</sup> with few comparisons of how

*See Invited Commentary at end of article*

diet or health is related to food resources within varying degrees of proximity.<sup>7,11</sup> 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.<sup>13</sup>

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 fruits 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<sup>7,13</sup> to underlie more commonly reported relationships between fast food availability and obesity<sup>14-16</sup>—and assess whether these relationships vary by individual-level income.

## METHODS

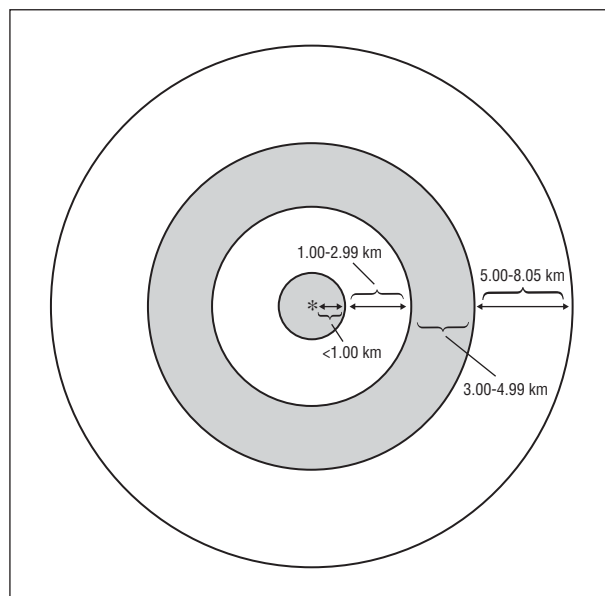
### STUDY POPULATION AND DATA SOURCES

The Coronary Artery Risk Development in Young Adults (CARDIA) study<sup>17</sup> is a population-based prospective study of the determinants and evolution of cardiovascular risk factors among young adults. At baseline (1985-1986), 5115 eligible subjects, aged 18 to 30 years, were enrolled with balance according to race, sex, education level ( $\leq$ high school or  $>$ high school) and age (18-24 or 25-30 years) from the populations of Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. Specific recruitment procedures have been described elsewhere.<sup>17</sup> Follow-up examinations conducted in the 1987-1988 period (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 US Census data to CARDIA respondent residential locations in examination 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. Additional data are available in eTables 1 through 8 (<http://www.archinternmed.com>).

### 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 data set of US businesses.<sup>18</sup> Food resources corresponding to each CARDIA examination period were extracted and classified according to 8-digit Standard Industrial Classification codes (eTable 1). Eight-digit codes were not available for the 1985-1986 period, so year 0 food stores were classified using 4-digit codes and textual queries designed for consistency with other examination years. Counts of each type of food resource were calculated within 1.00, 3.00, 5.00, and 8.05 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 were less than 1.61 km (75% of these by car), 62% of "social/recreational" trips were within 8.05 km,<sup>19</sup> and 72% of walking trips were under 1 km<sup>20</sup> (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 less than 1.00 km, from 1.00 to 2.99 km, 3.00 to 4.99 km, and 5.00 to 8.05 km of each respondent's residence (**Figure 1**).



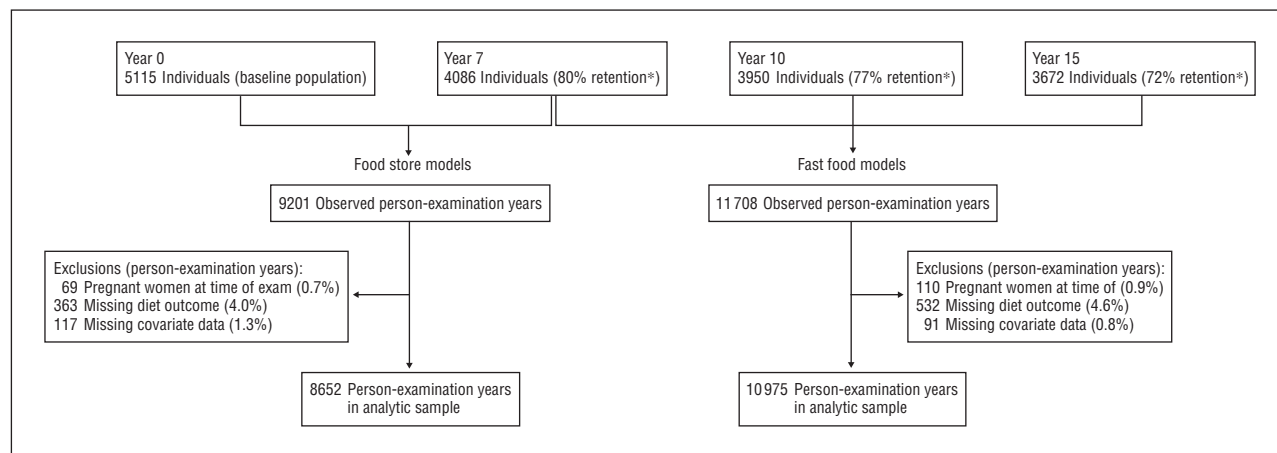
**Figure 1.** Concentric areas in which food resource availability was measured. The central asterisk indicates location of respondent residence. All concentric areas are measured in kilometers, as specified on the figure, and food resource availability was measured within each concentric area.

Within each concentric area, we calculated fast food restaurant and grocery store counts per 10 000 population and, owing 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<sup>21-23</sup> and other neighborhood characteristics.<sup>24</sup> Population within each area was derived from US 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 (eTables 6-8).

### DIET MEASURES

Frequency of chain fast food consumption was ascertained at each examination 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.<sup>25-27</sup> Diet quality was measured using the Diet Quality Index (DQI),<sup>28</sup> which quantifies adherence to the 2005 Dietary Guidelines for Americans<sup>29</sup>; scoring criteria are summarized in eTable 1. Briefly, the DQI incorporates adherence to recommendations for nutrients, food groups, and broader health messages (diversity, moderation, and minimization of added sugars); each category was 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



**Figure 2.** Summary of study retention and exclusions in the Coronary Artery Risk Development in Young Adults (CARDIA) study (1985-2000).<sup>17</sup> Asterisk indicates that retention incorporates loss to follow-up and mortality.

recommendations, a common marker of healthy dietary patterns,<sup>12</sup> 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.<sup>30,31</sup>

## CONTROL VARIABLES

In analyses, individual-level baseline characteristics included age (grand mean centered), race (white, black), and study center. Education ( $\leq$ high school, some college, or 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 or younger 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 US 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<sup>4</sup> and is independently related to diet,<sup>32</sup> we controlled for percentage of persons with household incomes less than 150% of federal poverty level ( $1.5 \times$  federal poverty level<sup>33</sup>) 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 less than 1 km and from 1 to 2.3 km but otherwise smaller than  $\pm 0.15$ ; 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  $P < .10$ ), 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 (eg, diet preferences that remain constant over time)<sup>9,34,35</sup>; in essence, each individual serves as his or her own control. 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 in several models, so for consistency, we report the more robust fixed-effects estimates for all models; corresponding random-effects estimates and Hausman tests are reported in eTables 6-8.

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.<sup>36</sup> As described elsewhere,<sup>35</sup> we treated 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, and sex) were 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 among whites and blacks: low,  $< \$20\,000$ ; medium,  $\$20\,000$ – $\$89\,900$ ; and high,  $\geq \$90\,000$ ); income-specific associations calculated from estimated main effect and income interaction coefficients are presented for models containing significant (Wald  $P < .10$ ) 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 eTables 4 and 5.

Due to differences in diet measures collected across CARDIA examination year, fast food availability in relation to fast food consumption (fast food model) was examined using examination years 7, 10, and 15; and supermarkets and grocery stores in relation to diet quality and fruit and vegetable intake (food store models) were examined using examination years 0 and 7. Study retention and exclusions are presented in **Figure 2**; analytical samples included 10 975 (fast food

model) and 8652 (food stores models) person-examination observations. Food resource data were complete for all observations, so exclusion was unrelated to the study exposures. In addition, 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, women reported healthier diets than men. eTable 3 summarizes neighborhood characteristics.

The relationship between neighborhood fast food restaurant availability and individual fast food consumption differed dramatically by income level (**Figure 3** and eTable 4) ( $P < .05$  for interaction). Among low-income men, a 1% increase in fast food availability within 1.00 km and from 1.00 to 2.99 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 among 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 adherence to fruit and vegetable recommendations (**Table 2**), with similar associations across income levels ( $P > .10$  for interaction). Supermarket availability within 1.00 to 2.99 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 1.00 to 2.99 km was related to significantly lower diet quality in high-income women, but higher diet quality in low-income men (**Figure 4** and eTable 5) ( $P < .10$  for interaction). Relationships between diet quality and grocery store availability also varied in magnitude and direction across concentric areas.

## COMMENT

Using a large, diverse, prospective cohort, we conducted the first longitudinal study that we know of 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<sup>1,2</sup> target fast food restaurants and food stores, with the assumption that they influence diet behaviors.

**Table 1. Individual-Level Sample Characteristics of the Respondents in the Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985-2000)<sup>17</sup> by Sex<sup>a</sup>**

Characteristic	Men (n=2208)	Women (n=2671)
White	51.0	47.1
Education <sup>b</sup>		
≥College graduation	33.9	35.2
Some college	8.2	10.6
≤High school	57.8	54.3
Married		
Never	73.0	65.8
Currently	20.7	23.9
Formerly	6.3	10.4
Children in household <sup>c</sup>	16.8	35.7
Age, y	24.8 (0.1)	24.9 (0.1)
Income, in \$10 000 US <sup>d</sup>	6.3 (0.1)	5.9 (0.1)
Fast food consumption, times/wk <sup>e</sup>	2.1 (0.0)	1.6 (0.0)
Diet Quality Index <sup>28e</sup>	46.5 (0.2)	53.0 (0.2)
Meets fruit and vegetable recommendations <sup>e</sup>	5.6	8.7

<sup>a</sup>Unless otherwise indicated, data are reported as percentage of respondents at baseline or mean (SE) value at baseline; all characteristics differed significantly by sex ( $P < .05$ ) except age.

<sup>b</sup>Education attained by year 7; imputed with education at year 0 where missing.

<sup>c</sup>Children or stepchildren living in household.

<sup>d</sup>Inflated to reflect value of 2001 US dollars.

<sup>e</sup>Pooled over examination years in which diet behavior was measured (fast food, years 7, 10, and 15; diet quality and fruit and vegetable consumption, years 0 and 7).

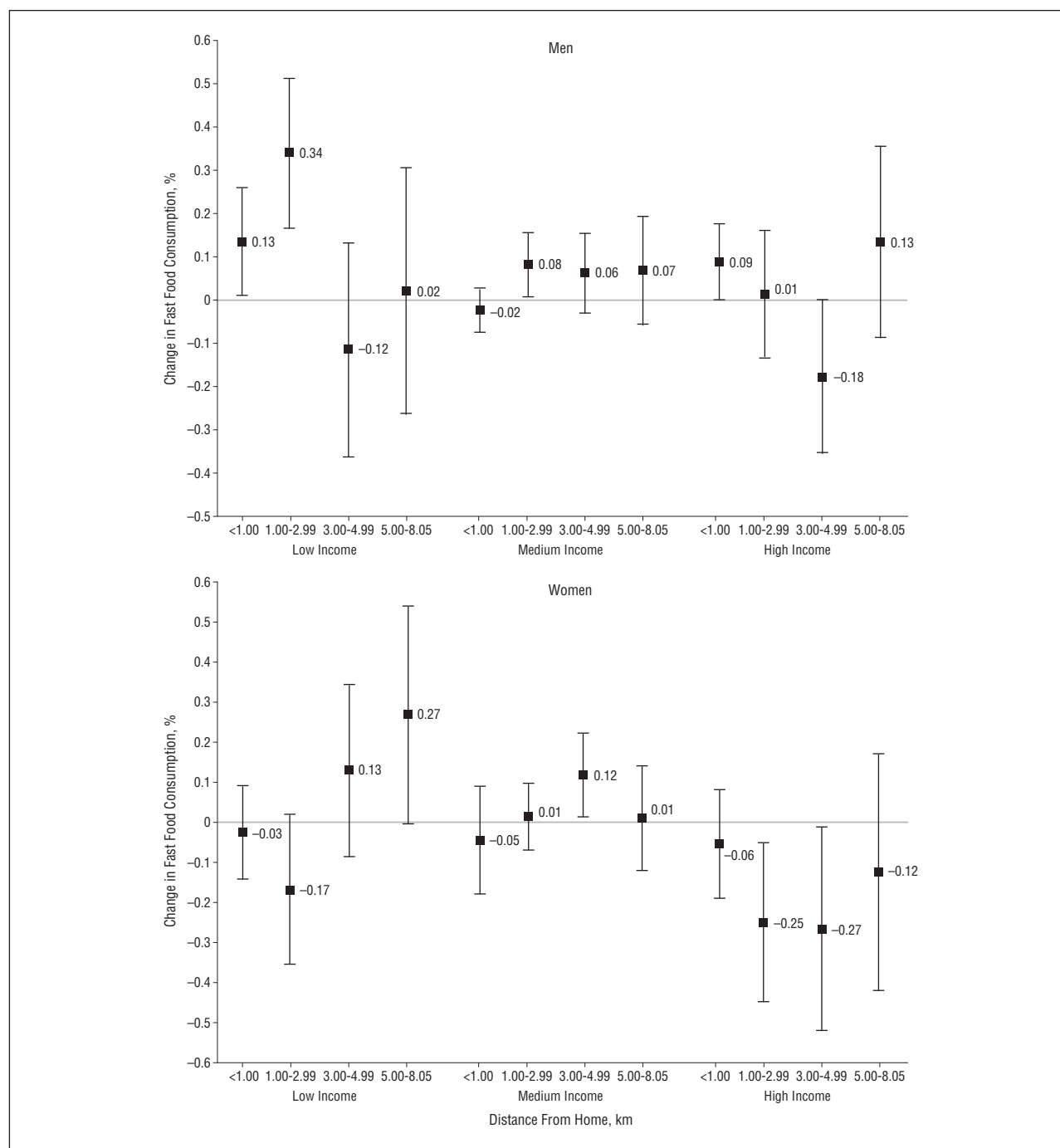
### Fast Food Chain Restaurants

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<sup>37</sup> and evidence of greater fast food availability<sup>4,5</sup> 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.<sup>15</sup> Owing to perceived cost or other barriers,<sup>38</sup> low-income individuals may be more sensitive to cues related to the presence of fast food restaurants.<sup>13</sup> 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.<sup>39</sup>

### Supermarkets

Most policies targeting food deserts focus on adding supermarkets to low-income areas<sup>1,5,40</sup>, with the expectation of increased consumption of healthy foods such as fruits and vegetables.<sup>41</sup> 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<sup>29</sup>).



**Figure 3.** Estimated effects of fast food availability within concentric areas around residential locations on weekly frequency of fast food consumption by individual-level income. Results were estimated using fixed-effects Poisson regression modeling fast food consumption (number of times per week) as a function of fast food restaurant availability (fast food restaurant counts per 10 000 population) in the areas within the distances indicated, measured in kilometers, from each Coronary Artery Risk Development in Young Adults (CARDIA) study (1985-2000)<sup>17</sup> respondent's home, adjusting for time-varying age, income, marital status, number of children in household, and percentage of persons whose household incomes fell below 150% of the federal poverty level. Race, education, and study center were 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 percentage change in fast food consumption expected from a 1% change in fast food restaurant availability. Error bars represent 95% confidence intervals.

Findings from our longitudinal analysis do not replicate findings from prior studies using similar measures. Analysis of 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 (eTables 6-8).<sup>4,42,43</sup> Our findings sug-

gest 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



**Table 2. Estimated Effects<sup>a</sup> of Food Stores Within Concentric Areas Around Residential Locations on Diet Quality and Adherence to Fruit and Vegetable Intake Recommendations**

Distance From Residence, km	Supermarkets				Grocery Stores <sup>b</sup>	
	DQI Coefficient (95% CI)	P Value	Meets Fruit and Vegetable Recommendations, OR (95% CI)		Meets Fruit and Vegetable Recommendations, OR (95% CI)	
			P Value		P Value	
Men (n=3921 <sup>c</sup> )						
<1.00	-0.05 (-0.60 to 0.50)	.86	1.10 (0.81 to 1.49)	.53	1.01 (0.63 to 1.62)	.96
1.00-2.99	-0.38 (-1.19 to 0.43)	.35	2.14 (1.19 to 3.83)	.01	1.20 (0.45 to 3.18)	.71
3.00-4.99	-0.01 (-0.97 to 0.95)	.98	1.02 (0.53 to 1.96)	.96	1.05 (0.33 to 3.35)	.94
5.00-8.05	0.60 (-0.51 to 1.71)	.29	0.58 (0.29 to 1.16)	.12	0.48 (0.10 to 2.23)	.35
Women (n=4731 <sup>c</sup> )						
<1.00	-0.19 (-0.71 to 0.32)	.46	0.93 (0.78 to 1.12)	.45	0.98 (0.69 to 1.38)	.89
1.00-2.99	-0.25 (-1.05 to 0.55)	.55	0.80 (0.59 to 1.08)	.15	1.20 (0.65 to 2.20)	.56
3.00-4.99	-0.38 (-1.28 to 0.53)	.42	0.90 (0.64 to 1.26)	.55	0.45 (0.20 to 1.02)	.06
5.00-8.05	0.58 (-0.42 to 1.58)	.26	1.45 (0.97 to 2.16)	.07	1.12 (0.50 to 2.54)	.78

Abbreviations: CI, confidence interval; DQI, Diet Quality Index<sup>28</sup>; OR, odds ratio.

<sup>a</sup>Estimated using fixed-effects linear (diet quality) or logistic (fruit and vegetable recommendations) regression modeling DQI<sup>28</sup> or adherence to 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 less than 1.00 km, 1.00 to 2.99 km, 3.00 to 4.99 km, and 5.00 to 8.05 km of each Coronary Artery Risk Development in Young Adults (CARDIA) study (1985-2000)<sup>17</sup> respondent's home, adjusting for time-varying age, income, marital status, number of children in household, and percentage of persons whose household incomes fell below 150% of federal poverty level. Race, education, and study center were time invariant and were therefore omitted from fixed-effects models. Coefficients can be interpreted as change in DQI expected from a 1% change in food store density; ORs can be interpreted as increased odds of meeting fruit and vegetable recommendations expected from a 1% change in food store density. Model 1 estimates were not significantly different from each other within sex.

<sup>b</sup>Estimated effects of grocery stores on diet quality varied significantly by individual-level income; income-specific estimates are shown in Figure 4.

<sup>c</sup>Counts (n) indicate number of person-year observations.

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.<sup>44</sup> An Institute of Medicine-National Academy of Science workshop<sup>45</sup> and more recent US Department of Agriculture research<sup>46</sup> also suggest that proximity to supermarkets may not be an important influence on diet, but experimental and quasi-experimental studies are needed in US settings.

### MOVING BEYOND FOOD RESOURCE AVAILABILITY

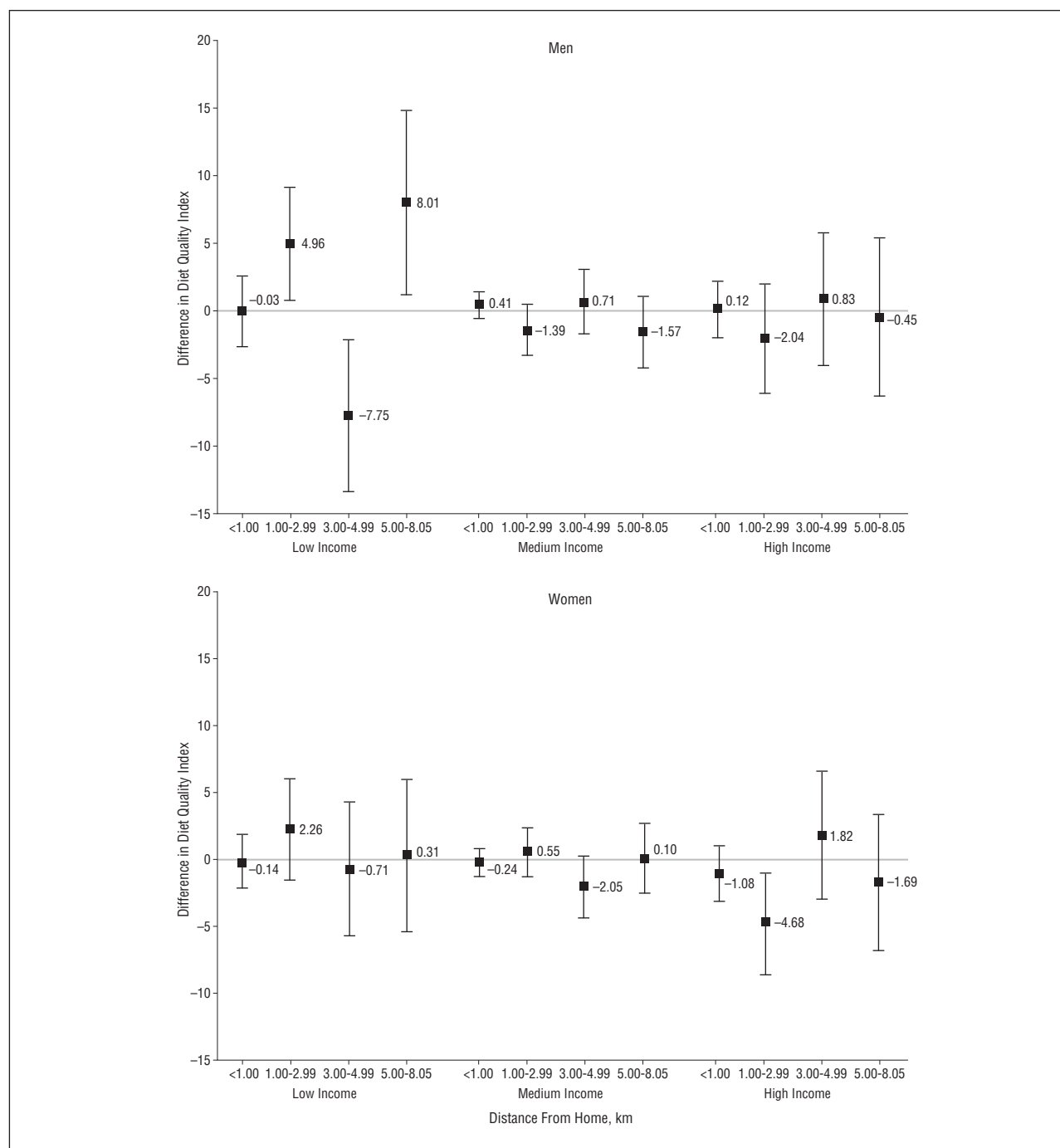
Another critical aspect of recent food environment policies is their focus on the availability (presence or quantity) of specific types of food stores or restaurants. Correspondingly, our study estimated how availability of chain fast food restaurants, supermarkets, and smaller grocery stores influences 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 mirrors contradictory conceptualizations of grocery stores as similar to supermarkets<sup>6,47</sup> or as less affordable, less healthy food stores.<sup>48,49</sup> 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.<sup>10</sup> In contrast, lower diet quality associated with greater grocery store availability nearby among 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.<sup>11</sup>

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<sup>50</sup> but could also reflect greater use by high-income women of nontraditional 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 vs 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 (eg, portion size, calorie content) or inequitable distribution among wealthy and poor neighborhoods appear to be unfounded.<sup>2</sup> Alternative or complementary policies include subsidies to small grocery stores for increasing access to specific foods such as produce and reduced-fat milk,<sup>5</sup> although corresponding research is similarly challenging without meaningful classifications of "healthy" or "unhealthy" food items. Cummins and colleagues<sup>41,44</sup> 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.



**Figure 4.** Estimated effects of grocery store availability within concentric areas around residential locations on diet quality by individual-level income. Results were estimated using fixed-effects linear regression modeling diet quality index as a function of grocery store counts per 10 000 population in the areas within the distances indicated, measured in kilometers, from each Coronary Artery Risk Development in Young Adults (CARDIA) study (1985-2000)<sup>17</sup> respondent's home, adjusting for time-varying age, income, marital status, number of children in household, and percentage of persons whose household incomes fell below 150% of the federal poverty level. Race, education, and study center were 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 Diet Quality Index<sup>28</sup> expected from a 1% change in grocery store density. Error bars represent 95% confidence intervals.

Furthermore, selection of foods from the surrounding food environment occurs within the macrolevel context of food production and pricing driven by the food industry and government regulation and the microlevel context of household financial resources and time constraints. For example, subsidizing the production of fruits and vegetables may reduce prices, encour-

age 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<sup>41</sup> 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 errors 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 year 0 vs year 7, although error is unlikely to vary systematically with diet behaviors. While our fast food restaurant availability measure excluded nonchain restaurants that may serve similar types of foods, it 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 businesses 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. In addition, capturing individual perceptions of neighborhood boundaries<sup>51</sup> 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<sup>52</sup> were far less (average error, 35 m) than the kilometer distances used in this study.

Finally, car ownership may influence relevant proximity to resources but was not collected in the CARDIA study. Inconsistencies may 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 United States and followed up into middle age.

## CONCLUSIONS

By promoting greater access to supermarkets, several US policies aim to improve diets through provision of affordable healthy foods, particularly fresh produce in underserved areas.<sup>1</sup> 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 diet quality across the income spectrum and that alternative policy options such as targeting specific foods or shifting food costs<sup>53</sup> (subsidization or taxation)<sup>2</sup> 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 youths 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 to help clinicians guide patients in overcoming practical barriers to healthy eating.

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