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Neighborhood food outlet access and dietary intake among adults with chronic kidney disease: Results from the Chronic Renal Insufficiency Cohort (CRIC) Study

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Abstract

Background: Healthy diet is essential in the management of chronic kidney disease (CKD) and preventing related comorbidities. Food outlet access has been studied in the general population; however, the influence of the local food environment on dietary intake among people with CKD has not been evaluated.

Objectives: This study examined the associations of food outlet density and type of outlets with dietary intake in a multicenter cohort of racially and ethnically diverse patients with CKD.

Methods: The Chronic Renal Insufficiency Cohort (CRIC) Study is a multicenter prospective study of patients with CKD that used a validated food frequency questionnaire to capture dietary intake at the baseline visit. This is a cross-sectional analysis of 2,484 individuals recruited in 2003-2006 from seven CRIC Study centers. Food outlet data was purchased to construct a count of the number of fast food restaurants, convenience stores, and grocery stores per 10,000 population for each geocoded census block group. Multivariable linear and logistic regression models were used to evaluate the associations between measures of food outlet availability and dietary factors.

Results: The proportion of participants living in zero, low, and high food outlet density areas differed by gender, race/ethnicity, and income level. Among males, living in areas with zero or the highest number of outlets was associated with having the highest caloric intakes in multivariable models. Males living in areas with zero outlets consumed the highest levels of sodium and phosphorous. Females living in areas with zero outlets had the lowest average intake of calories, sodium, and phosphorous. Among low-income females, close proximity to more outlets was associated with higher calorie consumption. Among all participants, access to fast food restaurants was not associated with an unhealthy diet score, nor access to grocery stores with a healthy diet score.

Conclusions: Average caloric and nutrient intakes differed by outlet availability; however, there were no strong associations with type of food outlet. This should be considered when developing food-focused public health policies.

Keywords

chronic kidney disease; chronic renal insufficiency; cohort study; food outlets; food environments; diet; eating behavior; CRIC (Chronic Renal Insufficiency Cohort)

Introduction

Public health messaging has increasingly called for increased access to healthy food. In the context of chronic kidney disease (CKD), access to foods that comprise a healthy diet may be especially relevant given the potential impact that behavioral interventions may have on the increased risk for cardiovascular disease (CVD) and mortality attributed to CKD. Evaluation of the associations between food access, diet and health outcomes has emerged as an area of interest as researchers try to explain health disparities that are not completely explained by individual behaviors. Local food environments vary and may contain grocery stores, convenience stores, and fast food restaurants. Prior studies in the general population have found higher fast food restaurant density to be associated with increased consumption of fast food[1,2] and decreased odds of having a healthy diet[3]. Food purchases from fast food and convenience stores may be unhealthy due to larger portions and high concentrations of sugar, fat, sodium and phosphate additives[4–6]. Consumption of processed foods has been associated with lower intakes of fruits, vegetables, fiber, and milk[7–9]. Past studies have shown that having no grocery stores or supermarkets nearby is associated with poor diet among both low-income[10] and mixed-income adults[11], but little is known about the association between access to food outlets and dietary patterns among individuals with CKD.

The investigation of these associations within a CKD population is particularly warranted given the roles diet and nutritional treatment play in the managing CKD and its comorbidities such as mineral and bone disorders[12,13]. Processed meats and cheeses, frozen meals, prepackaged baked goods, and colas could be particularly detrimental to health among individuals with CKD due to high concentrations of sodium- and phosphorus-based food additives[4,14]. Adjusting dietary phosphorus intake is one important aspect of the nutritional management of chronic kidney disease in adults[13]. In the general population, phosphorus intakes that exceed nutritional thresholds contribute to vascular calcification, impaired kidney function, and bone loss[15]. Prior studies of patients with CKD have shown high serum phosphate levels to be associated with CVD and increased mortality[4,16,17], indicating that high dietary phosphorus intake may be related to even worse health effects among persons with existing CKD.

Lower socioeconomic status has been associated with consumption of nutrient-poor and energy-dense diets[18,19], and food consumption and eating behaviors are known to differ by gender[20–22]. Decreased access to healthy food outlets like grocery stores and increased reliance on fast food outlets due to lower costs may be particularly burdensome on individuals with lower income[19,23]. Low socioeconomic status has also been associated with disparities among those with CKD[24,25] and there are documented differences in CKD prevalence and long-term health outcomes by gender[26–28]. Evaluation of the association between food outlet density and dietary characteristics overall, in addition to understanding if associations differ by gender or income levels may provide insights into tailored strategies to strengthen healthy eating interventions and encourage healthy living among subgroups of individuals with CKD.

This study uses data from the Chronic Renal Insufficiency Cohort (CRIC) Study to examine the density of different types of food outlets within close proximity to each participant's census block group among a cohort of individuals with CKD. The study then assessed the association between food outlet density and dietary intake and examined if the relationships between food outlet density and dietary intake differed by gender or income level.

Methods

Study sample

The CRIC Study is a prospective observational multicenter study of risk factors for the progression of CKD and cardiovascular disease in individuals with mild-to-moderate CKD. Details of the study design and baseline characteristics of study participants have been published [29,30] Participants were recruited between 2003 and 2008 from seven U.S. clinical centers in Ann Arbor, Michigan; Baltimore, Maryland; Chicago, Illinois; Cleveland, Ohio; New Orleans, Louisiana; Philadelphia, Pennsylvania; and Oakland, California. The flow diagram for sample exclusions is shown in Figure 1 (online supplementary material). A residential address that could be geocoded to the census block groups in the 2000 US Census was available for 2,930 of the 3,939 participants who completed the baseline visit. Four-hundred forty six participants chose not to report their income level and were excluded. Descriptive analyses were restricted to the 2,484 participants with measures of food outlet density and self-reported income data available. An additional 595 were missing information on dietary intake, either due to incomplete data from diet history questionnaires or exclusion by the data coordinating center due to implausible values. The final analytic sample to evaluate associations with diet included 1,889 participants. The CRIC study was approved by the local institutional review board at each clinical center, and participants provided written informed consent.

Outcome variables

Information on dietary intake was collected at the baseline CRIC study visit using a validated food frequency questionnaire developed by the National Cancer Institute (NCI)[31]. Participants recalled portion size and frequency from 124 food items consumed over the preceding 12 months. This information was analyzed using the NCI's DietCalc software and output as total caloric intake (kcal/day); percentage of calories from carbohydrates, saturated fat, and protein; protein (g/day); saturated fat (g/day); calcium (mg/day); sodium (mg/day); phosphorous (mg/day); cholesterol (mg/day); and sugar-sweetened beverages (ounces/week). Study outcomes also included the number of servings of fruits, vegetables, and whole grains that each participant consumed per day. An overall diet score adapted from the American Heart Association's recommendations for cardiovascular health[32] was calculated by scoring each participant's diet by assigning one point for having above the median values for 1) fruit/vegetable servings per day, 2) fish servings per week, and 3) whole grain servings per day and below the median values for 4) 24-hour urine sodium excretion, and 5) sweets/sugary beverage portions per week[33]. The diet score ranged from 0 to 5 and in this study the diet score was dichotomized into a "healthy diet" for those that scored 4 to 5 points and "unhealthy diet" for those that scored 0 to 3 points as has been done in prior studies[33].

Exposure variables

Food outlet data for the CRIC enrollment period was obtained from Dun and Bradstreet's (D&B), and the count of food outlets was matched to the enrollment year for each participant. Standard Industrial Classification (SIC) codes as listed in Table 1 (online supplementary material) were used to classify outlets by type (fast food restaurant, convenience store, or grocery store), to create an annual estimate of each type of outlet for each participant based on their year of their enrollment. Using Geographic Information System software (ArcGIS, version 10.3) each food outlet was geocoded using the address and x and y coordinates provided by D&B and defined 1 kilometer (1km) concentric areas (Euclidean buffer) from each participant's census block group centroid. Within each buffer, counts of fast food restaurants, convenience stores, and grocery stores were calculated and standardized per 10,000 population using the 2000 US Census block group population data. Prior studies have used scaled measures of food outlets to account for the development of a particular geographic area[34,35]. When there was overlap between block group buffers, the proportion of each block group area buffer that overlapped with another block group area buffer was calculated and the counts of food outlets were adjusted to address the overlap with other block group buffers.

The food outlet data was used to construct six measures of food outlet availability within 1km. This distance has been used in previous studies to capture food outlets accessible by walking[36–39]. In addition to separate counts of fast food restaurants, convenience stores, and grocery stores per 10,000 population, the fast food restaurant and convenience store counts were added together to construct a measure of hypothesized "unhealthy" food outlets. To capture total access to food outlets, the counts of fast food restaurants, convenience stores, and grocery stores were summed. The modified retail food environment index (mRFEI)[40,41] was calculated as a measure of the mixed retail food environment. This index represents the percentage of food outlets in a given area that are more likely to sell healthy food and is calculated by dividing the number of grocery stores by the sum of fast food restaurants, convenience stores, and grocery stores.

After examining the distribution of each food outlet measure, fast food restaurants, the sum of fast food restaurants and convenience stores, and the total sum of outlets were categorized into quartiles based on their distribution. Due to the smaller number of convenience and grocery stores, those outlets were categorized into tertiles based on their distribution. The proportion with zero outlets was considered the referent group for all measures. The mRFEI was grouped into four categories: 1) no food outlets, 2) only fast food restaurants or convenience stores, 3) ≤20% of outlets are grocery stores, and 4) 21-100% of outlets are grocery stores.

Covariates

At baseline, information was collected on age, gender, race/ethnicity, marital status, annual income, education level, diabetes status, hypertension status, urinary protein level, and estimated glomerular filtration rate (eGFR) measured using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula [42].

Statistical analysis

Descriptive statistics were calculated for demographic and clinical characteristics, overall and stratified by categories of food outlet density. Characteristics were summarized as mean (± standard deviation) or medians with interquartile range (IQR) for continuous variables, and as frequencies (proportions) for categorical variables. Bivariate comparisons between groups utilized analysis of variance or chi-square tests as appropriate. Natural log transformations were applied to skewed dietary outcomes. Individual linear and logistic regression models were used to evaluate the associations between each measure of food outlet availability and the outcomes (e.g., dietary factors and healthy diet score). Model estimates were compared to multilevel linear regression models with a random intercept and logistic models using an exchangeable correlation structure to account for clustering of participants, but estimates did not substantively differ when using multilevel models. Additionally, there were sparse numbers per cluster, resulting in zero estimates for the random intercept variance in multiple instances. Therefore geometric means with 95% confidence intervals (95% CI), or odds ratios (OR) with 95% CI were estimated from simple linear and logistic regression models after controlling for study center, age (continuous), gender (male/female), race (non-Hispanic white, non-Hispanic black and other), annual income (less than \$20,000, \$20,000 to \$50,000, or greater than/equal to \$50,000), education level (less than high school, high school graduate, some college, or college graduate or more), and marital status (never, formerly, or currently married). Post-hoc adjustments for multiple comparisons using Tukey's test did not substantively change the reported results. Effect modification was evaluated by gender and income by adding a cross-product term between the measure of food outlet density within 1km and the effect modifier of interest to the regression model. A p-value of 0.05 was considered statistically significant when evaluating effect modification. When effect modification was detected, estimates are presented stratified by the effect modifier.

Results

Among the 2,484 participants in our study sample, the median age was 60 years (IQR 52-66) and 54% were male (Table 2). Median dietary sodium intake was 2587 mg per day (IQR 1862-3608), and dietary phosphorous intake was 1053 (IQR 746-1415) mg per day. There was a median of 3 (IQR 1-7) fast food restaurants within 1km of the census block groups, and a median of 5 outlets (IQR 1 to 9) when fast food restaurants and convenience stores were combined into a single measure. Within 1km, there were few grocery stores. Over half (n=1,428; 57.5%) of participants had zero grocery stores within 1km of their census block group.

Relative to males, a smaller proportion of females lived in areas with zero fast food restaurants ($p=0.003$) or zero convenience stores ($p=0.01$) within 1km (Table 3; online supplementary material). Overall, a larger proportion of females than males had access to food outlets, but the food outlets that were most available to females included fast food restaurants and convenience stores. The proportion of participants with access to grocery stores did not differ by gender ($p=0.28$). Compared to black and other race participants, a larger proportion of white participants had zero fast food restaurants ($p<0.0001$), zero convenience stores ($p<0.0001$), and zero grocery stores ($p<0.0001$) within 1km of the census block group. A large proportion of white (40.3%) and black (43.4%) participants lived in areas with only fast food restaurants and convenience stores within 1km; however, a larger proportion of black and other race participants had access to grocery stores compared to whites. Across strata of income, a larger proportion of people with the highest income had zero fast food restaurants ($p<0.0001$), convenience stores ($p<0.0001$), and zero grocery stores ($p<0.0001$) relative to those who reported lower income. As income increased, the proportion living in areas densely populated with fast food restaurants decreased ($p<0.0001$). The majority with income under $20,000 per year lived in an environment with many food outlets ($p<0.0001$), which included a mix of fast food restaurants, convenience stores, and grocery stores.

Compared to the overall sample, the characteristics of the 1,889 study participants with complete diet data were mostly similar. There were small differences with respect to race/ethnicity, income, and educational attainment. A larger proportion of participants with complete diet data were non-Hispanic white (51.1% vs. 42.1% overall) compared to other race/ethnicity (8.9% vs. 18.9% overall), had at least a college education (38.4% vs. 32.5% overall) relative to a less than high school education (13.4% vs. 21.0% overall), and reported an income level greater than $50,000 per year (40.5% vs. 34.6% overall) compared to those that reported an income less than $20,000 per year (29.3% vs. 36.6% overall). In regards to associations between food outlet availability and dietary characteristics, study participants with complete diet data consumed similar average percentages of calories from saturated fats, carbohydrates, or protein regardless of the numbers or types of food outlets within 1km of their census block group. There were no meaningful differences in the average levels of saturated fat (g/day), calcium (mg/day), sugary beverages (ounces/week) consumed by participants living near different densities of food outlet availability, nor did self-reported intakes of fruits, vegetables, and whole grains differ among groups of participants living near different numbers or categorizations of food outlets (data not shown).

In the individual models for daily caloric intake (kcal/day), phosphorous (mg/day), sodium (mg/day), and cholesterol (mg/day) outcomes, many estimates of consumption levels differed by gender. Gender stratified estimates of average daily intake of calories, phosphorous, sodium, and cholesterol by different categorizations of food outlets are shown in Table 4. Among males, daily caloric intake varied by number of fast food outlets available and exhibited a u-shaped distribution where males living within close proximity to zero fast food outlets and eight or more outlets had the highest average daily caloric intakes (1953 kcal/day vs. 1920 kcal/day). Males living in areas with zero food outlets within 1km had high average levels of sodium and phosphorous consumption (3046 mg/day sodium and 1187 mg/day phosphorous). Females living in areas with increasing numbers of fast food restaurants relative to areas with zero food outlets reported consuming higher average levels of dietary cholesterol (140 mg/day among those with zero restaurants vs. 169 mg/day among those with 4 to 7 restaurants). Among females, daily caloric, sodium, and phosphorous intakes were lowest among those living in zero food outlet areas.

When the associations between food outlets and dietary characteristics were further evaluated to determine if associations additionally differed by income level, associations among males did not differ by income level (p for interaction 0.10 to 0.98). Among females, some associations appeared to differ by income level. Specifically, the association between availability of food outlets and caloric intake among females differed by income level, particularly in respect to fast food restaurants (p-interaction 0.03), and the modified retail food environment index (p-interaction 0.01). The association between grocery store availability and phosphorous consumption differed by income level among females (p-interaction 0.05). Table 5 shows the adjusted associations between food outlet density with total daily caloric and phosphorous intake among females by income level. Females who reported income levels less than $20,000 and had the highest density of grocery stores consumed higher average daily calories relative to females in the same income group with zero grocery stores. Increased availability of grocery stores was also associated with increased phosphorous consumption among females with incomes less than $20,000.

A total of 408 (21.6%) participants had a diet score that was considered healthy, and 38.0% (n=155) of those with a healthy diet score lived in areas with only fast food and convenience store options (Table 6; online supplementary material). When odds of having a healthy diet were modeled using logistic regression, food outlet availability did not appear to be strongly associated with odds of having a healthy diet. There was no evidence of effect modification by gender or income level.

Discussion

This study is the first to examine the availability of fast food restaurants, convenience, and grocery stores in a diverse cohort of adults with mild-to-moderate CKD. The results show that residential proximity to food outlets varies by gender, race/ethnicity, and income, and may be most influential on dietary behaviors among females with CKD and low income. Most participants had at least one fast food restaurant or convenience store within one kilometer of their census block group. Contrary to expectation, this study did not show strong trends between access to fast food or convenience stores outlets and unhealthy diet, nor did the study find that access to grocery stores is associated with healthy diet among individuals with CKD. The study did; however, detect patterns with specific nutrients, suggesting that the food environment influences dietary choices. Outlet density by gender interactions suggested differences in patterns of calorie and nutrient consumption that may be important to take into consideration when planning interventions or developing health policies aimed at the neighborhood food environment. A large portion of the work surrounding health policies at the neighborhood level has focused on obesity prevention in the general population[43–46]. The lack of a direct one-to-one correlation between food environment and diet that can be pooled across the population irrespective of differences by gender or socioeconomic status has implications for healthy living policies and community-level interventions aimed at protecting public health. This is an important consideration that may impact public health initiatives such as those led by the Centers for Disease Control and Prevention (CDC) National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity and Obesity[47], which are intended to increase access to healthy food by informing health policies aimed at improving food environments.

Prior studies have evaluated gender differences in dietary intakes, reporting increased energy intake among males compared to females[48]. In the Framingham Study, larger proportions of females relative to males met dietary recommendations for carbohydrate, saturated fat, and cholesterol consumption[49]. Gender differences in relation to the association between food outlet access and dietary consumption has not been well described. In this study, males living in zero outlet areas consistently had the highest average intakes of calories, phosphorous, and sodium, which were similar to the levels among males living in areas with eight or more fast food restaurants and opposite of what was observed among females. The average daily sodium intake among males exceeded the recommended level of 2,000 mg[50]. Females in zero outlet areas consistently had low average intakes for dietary components, with additional differences by income level. Despite recommendations that dietary phosphorous intake be restricted to a maximum of 800 to 1,000 mg/day[51], females with higher income levels consumed more phosphorous in areas where the number of fast food outlets were greatest (zero outlets 946 mg/day vs. 8+ fast food outlets 1121 mg/day). This contrasts with females with the lowest income, where the highest intake of phosphorous (1141 mg/day) was among those with access to two or more grocery stores. The diversity of these findings may be an indication that one size fits all neighborhood level interventions or policies aimed at improving dietary practices by restricting fast food outlets or increasing the number of grocery stores need careful evaluation before large scale implementation.

Many food environment studies have examined associations of food outlet density with diet individually, focusing on grocery stores or fast food restaurants in isolation without considering the impact of living in a mixed food environment where access to all of these outlets exists in the same space[1,3,6,52]. While these studies add valuable information to our understanding of the impact the food environment has on health, understanding the implications of the food environment requires us to consider the context of the mixed food environment. Consistent with other multi-center epidemiologic studies[11,34,53], this study examined the associations between dietary factors and a diverse food environment that considered a variety of food outlet sources.

Unlike the Multi-Ethnic Study of Atherosclerosis (MESA) study, in this study there was no evidence of an association between the availability of fast food outlets and the odds of a healthy diet[3]. This may be due to differences between the study groups, small sample size in our sample due to the applied exclusion criteria, or the different metrics used to measure diet. In the Coronary Artery Risk Development in Young Adults (CARDIA) study, greater access to supermarkets was associated with poor quality diet among high-income women, but better quality diet among low-income men[34]. In the current study access to a higher number of grocery stores was associated with higher consumption of total calories among female participants with the lowest income level. This discordance may be due to differences in age between the two studies; the average age of participants in this study was more than double that of CARDIA. In the Atherosclerosis Risk in Communities (ARIC) study, increased access to supermarkets was associated with increased fruit and vegetable intake among black and white participants[53]. The current study did produce evidence to support grocery store access being associated with fruit and vegetable intake or better dietary habits, as the majority of dietary intakes measured did not meaningfully differ according to number of grocery stores. To date, findings from other studies have not consistently supported the hypothesis that increased access to grocery stores and supermarkets is associated with better dietary practices[54–57]. In the context of CKD, this null finding may be due to differences in eating habits among people with CKD that are independent of food outlet availability, such as recommendations from their health care provider to follow a renal diet.

This study has several limitations. It used an ecological approach linking individual behaviors and outcomes with census block group level food outlets, using the geocoded census block group as a proxy for neighborhood. Participants in this study were not asked about fast food eating behavior or about sources of food and beverage. This study is unable to precisely link proximity to food outlets to individual eating behaviors. The food frequency questionnaire may not accurately capture sodium and phosphorous, and the methodology used to estimate individual nutrients does not capture sodium or phosphorus-based additives such as dicalcium phosphate, sodium aluminum phosphate, or sodium phosphate; therefore, this study may be underestimating true consumption levels. The possibility of measurement error in the food frequency questionnaire, or in the food outlet data source cannot be ruled out. This study assumed that proximity to food outlets could be used to infer patronage at surrounding food outlets due to participants' ability to walk to outlets; however, neighborhood walkability was not measured nor were individual physical limitations that preclude walking to these outlets considered. The assessment of food outlets only occurred at baseline (2003 to 2008), not accounting for changes in neighborhood outlets over time, nor access to food outlets surrounding work places or other communities that participants may frequent. Fast food restaurants and convenience stores were considered to be sources of unhealthy food, but this study cannot account for healthy items that may have been available at these outlets. Numerous participants did not report their income level or dietary characteristics and were excluded from analyses. Although the participants in this study sample had similar levels of kidney function compared to the overall CRIC cohort, the demographics of these participants may not be completely representative of the overall cohort, as participants who were non-Hispanic white, college educated, and had higher income may be overrepresented related to participants of other race or who had less than a high school education or lower income level. Despite these limitations, the CRIC study data provides a unique opportunity for scientific investigation to better understand how neighborhood level food outlet density impacts diet in a well-defined cohort of people with CKD.

Understanding how food outlet density affects dietary consumption and subsequent health outcomes among people of varying socioeconomic backgrounds living with chronic disease is imperative to our work to protect public health. The results from this study indicate that strategies to increase adherence to a healthy diet must go beyond simply advising people with CKD to avoid purchasing food from fast food restaurants. Future investigations may benefit from combining spatial analysis to determine food outlet availability with questions about dietary consumption behaviors, shopping and dining preferences, and awareness of food and drinks that contain unhealthy additives. Ultimately, awareness of the food outlets available at the neighborhood level provides context into how people with CKD access food and may enhance intervention strategies aimed at improving dietary behaviors to promote health in this growing portion of the population living with chronic disease.

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Abbreviations:

CRIC	Chronic Renal Insufficiency Cohort
CKD	Chronic kidney disease

NCI	National Cancer Institute
D&B	Dun and Bradstreet
SIC	Standard Industrial Classification
mRFEI	Modified retail food environment index
eGFR	Estimated glomerular filtration rate
CKD-EPI	Chronic Kidney Disease Epidemiology Collaboration
95% CI	95% confidence interval
OR	Odds ratios
IQR	Interquartile range
MESA	Multi-Ethnic Study of Atherosclerosis Study
CARDIA	Coronary Artery Risk Development in Young Adults Study
ARIC	Atherosclerosis Risk in Communities Study

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Research Snapshot

Research Question:

How does neighborhood food outlet access impact dietary intake among people with chronic kidney disease? Do these associations differ by gender or income level?

Key Findings:

A U-shaped pattern was observed among males in relation to total caloric consumption. Having zero food outlets nearby was associated with the highest consumption levels of sodium and phosphorous among males. Among females, living in an area with zero food outlets was associated with the lowest average intake of calories, sodium, and phosphorous. Associations between access to outlets and dietary intakes among females differed by income level. Among low-income females, access to more outlets were associated with higher calorie consumption.

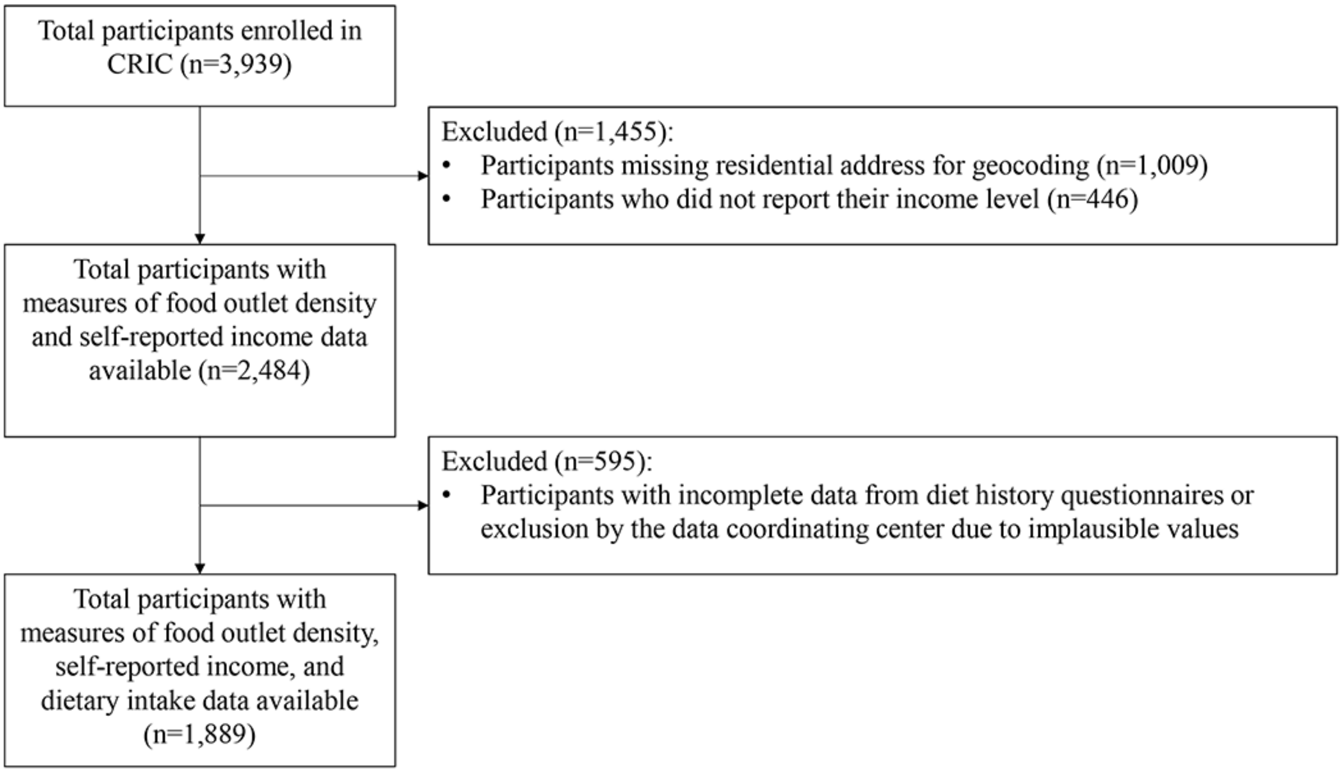

Figure 1.
Participant flow diagram showing sample exclusions and final numbers for statistical analysis.

Table 1.

United States Department of Labor Standard Industrial Classification (SIC)[a] codes and definitions used to group food outlets into types

Food Outlet Type	SIC Code	SIC Definition
Fast Food	58120300	Fast Food Restaurants and Stands
	58120301	Box Lunch Stand
	58120302	Carry-out only
	58120303	Chili Stand
	58120304	Coffee Shop
	58120305	Delicatessen (eating places)
	58120306	Drive-in Restaurant
	58120307	Fast-Food Restaurant, Chain
	58120308	Fast-Food Restaurant, Independent
	58120309	Food Bars
	58120310	Grills (eating places)
	58120311	Hamburgers stand
	58120312	Hot dogs stand
	58120313	Sandwiches and Submarines Shop
	58120314	Snack Bar
	58120315	Snack Shop
	58120601	Pizzeria, Chain
	58120602	Pizzeria, Independent
Grocery stores	541101	Grocery stores
	541104	Food products – retail
	541106	Grocers – retail
	541107	Markets – kosher
	541108	Grocers – ethnic foods
	541109	Grocers – health foods
Convenience stores	5331	Variety Stores
	541102	Convenience stores

[a]Occupational Safety and Health Administration. Standard Industrial Classification Manual. United States Department of Labor. https://www.osha.gov/pls/imis/sic_manual.html. Published 2019. Accessed 10/28/2019

Table 2.

Baseline demographic characteristics of Chronic Renal Insufficiency Cohort (CRIC) Study participants with available data linkage on food density, n=2,484

	Overall (n=2,484)
Characteristic	**n (%)**
Age, years [median (IQR[a])]	60 (52-66)
Gender, Male	1347 (54.2)
Race/ethnicity, White, nH[b]	1046 (42.1)
Black, nH	969 (39.0)
Other	469 (18.9)
Income	
<$20,000	908 (36.6)
$20,001 - $50,000	716 (28.8)
>$50,001	860 (34.6)
Education	
Less than HS[c]	522 (21.0)
HS graduate	439 (17.7)
Some college	715 (28.8)
≥College graduate	808 (32.5)
Marital status, currently married	1361 (54.8)
Formerly married	764 (30.8)
Never married	359 (14.4)
Medical History	
Hypertension	2148 (86.5)
Diabetes mellitus	1235 (49.7)
Cardiovascular disease	812 (32.7)
eGFR[d], ml/min per 1.73m^2 [mean (SD[e])]	43.6 (14.9)
Proteinuria, g/day [median (IQR)][f]	0.19 (0.07-0.96)
Food outlets per 10,000 people within 1 kilometer [median (IQR)]	
Fast food restaurants	3 (1-7)
Convenience stores	1 (0-2)
Fast food restaurants + convenience stores	5 (1-9)
Grocery stores	0 (0-1)
Total food outlets	5 (1-10)

[a]IQR=interquartile range

[b]nH=non-Hispanic

[c]HS=high school

[d] eGFR=estimated glomerular filtration rate (Note, eGFR of 60 or higher is considered to be in the normal range.)

[e] SD=standard deviation

[f] n=2782 overall for 24H Urine Protein (g/24Hours)

Table 3.

Demographic characteristics among Chronic Renal Insufficiency Cohort (CRIC) Study participants with complete income data (n=2,484) by categories of food density within one kilometer of census block group at baseline

Number of outlets within one kilometer		Overall	Gender		Race/ethnicity			Income		
			Male	Female	Black, nH[a]	White, nH	Other	<$20,000	$20,001 - $50,000	>$50,001
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Fast food	Zero	576 (23.2)	356 (26.4)	220 (19.3)	134 (13.8)	390 (37.3)	52 (11.1)	101 (11.1)	158 (22.1)	317 (36.9)
	1-3	694 (27.9)	360 (26.7)	334 (29.4)	305 (31.5)	297 (28.4)	92 (19.6)	245 (27.0)	207 (28.9)	242 (28.1)
	4-7	657 (26.5)	331 (24.6)	326 (28.7)	299 (30.9)	174 (16.6)	184 (39.2)	330 (36.3)	179 (25.0)	148 (17.2)
	8+	557 (22.4)	300 (22.3)	257 (22.6)	231 (23.8)	185 (17.7)	141 (30.1)	232 (25.6)	172 (24.0)	153 (17.8)
	p-value		0.0003		<0.0001			<0.0001		
Convenience stores	Zero	994 (40.0)	574 (42.6)	420 (36.9)	258 (26.6)	593 (56.7)	143 (30.5)	247 (27.2)	250 (35.0)	497 (57.8)
	1-2	959 (38.6)	488 (36.2)	471 (41.4)	423 (43.7)	315 (30.1)	221 (47.1)	423 (46.6)	288 (40.2)	248 (28.8)
	3+	531 (21.4)	285 (21.2)	246 (21.7)	288 (29.7)	138 (13.2)	105 (22.4)	238 (26.2)	178 (24.8)	115 (13.4)
	p-value		0.01		<0.0001			<0.0001		
Fast food + Convenience stores	Zero	481 (19.4)	302 (22.4)	179 (15.7)	91 (9.4)	345 (33.0)	45 (9.6)	70 (7.7)	126 (17.6)	285 (33.1)
	1-4	715 (28.8)	379 (28.2)	336 (29.6)	294 (30.3)	328 (31.4)	93 (19.8)	243 (26.8)	210 (29.3)	262 (30.5)
	5-9	719 (28.9)	357 (26.5)	362 (31.8)	334 (34.5)	193 (18.4)	192 (40.9)	352 (38.8)	201 (28.1)	166 (19.3)
	10+	569 (22.9)	309 (22.9)	260 (22.9)	250 (25.8)	180 (17.2)	139 (29.7)	243 (26.7)	179 (25.0)	147 (17.1)
	p-value		0.0001		<0.0001			<0.0001		
Grocery stores	Zero	1428 (57.5)	793 (58.9)	635 (55.9)	507 (52.3)	750 (71.7)	171 (36.5)	416 (45.8)	424 (59.2)	588 (68.4)
	1	593 (23.9)	315 (23.4)	278 (24.4)	269 (27.8)	196 (18.7)	128 (27.3)	255 (28.1)	167 (23.3)	171 (19.9)

Number of outlets within one kilometer		Overall	Gender		Race/ethnicity			Income		
			Male	Female	Black, nH[a]	White, nH	Other	<$20,000	$20,001 - $50,000	>$50,001
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
	2+	463 (18.6)	239 (17.7)	224 (19.7)	193 (19.9)	100 (9.6)	170 (36.2)	237 (26.1)	125 (17.5)	101 (11.7)
	p-value		0.28		<0.0001			<0.0001		
All food outlets	Zero	455 (18.3)	286 (21.2)	169 (14.8)	86 (8.9)	329 (31.5)	40 (8.5)	66 (7.3)	122 (17.0)	267 (31.0)
	1-5	801 (32.3)	433 (32.2)	368 (32.4)	322 (33.2)	372 (35.6)	107 (22.8)	269 (29.6)	231 (32.3)	301 (35.0)
	6-10	646 (26.0)	313 (23.2)	333 (29.3)	305 (31.5)	174 (16.6)	167 (35.6)	314 (34.6)	187 (26.1)	145 (16.9)
	11+	582 (23.4)	315 (23.4)	267 (23.5)	256 (26.4)	171 (16.3)	155 (33.1)	259 (28.5)	176 (24.6)	147 (17.1)
	p-value		<0.0001		<0.0001			<0.0001		
Modified retail food environment index	Zero	455 (18.3)	286 (21.2)	169 (14.8)	86 (8.9)	329 (31.4)	40 (8.5)	66 (7.3)	122 (17.0)	267 (31.1)
	FFR+CS[b] only	973 (39.2)	507 (37.7)	466 (41.0)	421 (43.4)	421 (40.3)	131 (27.9)	350 (38.5)	302 (42.2)	321 (37.3)
	GS[c]: FFR+CS≤0.2	716 (28.8)	381 (28.3)	335 (29.5)	314 (32.4)	206 (19.7)	196 (41.8)	338 (37.2)	198 (27.7)	180 (20.9)
	GS: FFR+CS>0.2	340 (13.7)	173 (12.8)	167 (14.7)	148 (15.3)	90 (8.6)	102 (21.8)	154 (17.0)	94 (13.1)	92 (10.7)
	p-value		0.001		<0.0001			<0.0001		

[a] nH=non-Hispanic;

[b] FFR+CS= fast food restaurants and convenience stores;

[c] GS= grocery stores;

Table 4.

Multivariable adjusted[a] associations between categories of food density within one kilometer of census block group and dietary characteristics among males and females with complete income and diet data in the CRIC cohort (n=1889)

		Caloric intake (kcal/day)		Phosphorous (mg/day)		Sodium (mg/day)		Cholesterol (mg/day)	
Number of outlets within one kilometer		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
		GM[b] (95% CI)	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**
Fast food	Zero	1953 (1837-2077)	1353 (1261-1451)	1180 (1106-1259)	844 (782-909)	3074 (2877-3286)	2089 (1935-2255)	245 (223-268)	140 (126-155)
	1-3	1770 (1671-1875)*	1464 (1381-1552)*	1106 (1040-1176)	912 (856-970)	2903 (2727-3090)	2255 (2116-2404)	235 (216-256)	165 (152-180)*
	4-7	1880 (1769-1999)	1503 (1415-1596)*	1144 (1072-1221)	949 (889-1012)*	2876 (2691-3073)	2317 (2169-2476)*	236 (215-258)	169 (154-185)*
	8+	1920 (1803-2046)	1396 (1304-1495)	1177 (1100-1258)	876 (814-943)	3065 (2862-3282)	2127 (1974-2292)	245 (223-269)	156 (141-173)
	p-value	0.02	0.06	0.25	0.06	0.19	0.08	0.77	0.02
Convenience stores	Zero	1882 (1785-1986)	1436 (1359-1518)	1165 (1101-1232)	911 (858-967)	2989 (2822-3167)	2230 (2098-2370)	245 (227-265)	153 (141-167)
	1-2	1840 (1744-1940)	1464 (1389-1544)	1115 (1054-1180)	913 (862-966)	2871 (2711-3041)	2247 (2121-2381)	226 (209-245)	166 (154-180)
	3+	1907 (1790-2032)	1401 (1307-1501)	1174 (1097-1255)	868 (806-935)	3085 (2880-3304)	2129 (1974-2296)	252 (229-277)	157 (142-175)
	p-value	0.56	0.51	0.27	0.44	0.15	0.43	0.07	0.24
Fast food + convenience stores	Zero	1949 (1825-2080)	1345 (1245-1453)	1188 (1108-1274)	846 (779-919)	3060 (2850-3284)	2102 (1932-2288)	245 (222-270)	137 (122-154)
	1-4	1820 (1719-1927)*	1487 (1404-1575)*	1136 (1070-1207)	920 (864-978)	2952 (2775-3141)	2283 (2143-2431)	239 (219-260)	166 (152-181)*
	5-9	1849 (1742-1963)	1458 (1375-1545)	1122 (1053-1196)	925 (869-985)	2870 (2690-3062)	2243 (2104-2391)	234 (214-256)	164 (151-179)*
	10+	1910 (1795-2033)	1409 (1316-1508)	1166 (1092-1245)	880 (818-947)	3041 (2843-3252)	2148 (1994-2314)	243 (222-267)	159 (144-176)*
	p-value	0.20	0.11	0.46	0.21	0.37	0.27	0.86	0.02
Grocery stores	Zero	1853 (1766-1945)	1436 (1371-1504)	1140 (1083-1200)	898 (855-944)	2948 (2797-3107)	2207 (2098-2322)	234 (218-251)	157 (147-169)

		Caloric intake (kcal/day)		Phosphorous (mg/day)		Sodium (mg/day)		Cholesterol (mg/day)	
Number of outlets within one kilometer		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
		GM[b] (95% CI)	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**	**GM (95% CI)**
	1	1873 (1762-1992)	1400 (1309-1497)	1142 (1070-1219)	869 (809-933)	3014 (2820-3221)	2185 (2030-2351)	239 (219-262)	163 (147-180)
	2+	1922 (1786-2067)	1501 (1393-1618)	1177 (1089-1271)	955 (881-1035)	2960 (2735-3203)	2281 (2101-2476)	255 (229-284)	163 (146-182)
	p-value	0.65	0.31	0.74	0.16	0.81	0.68	0.35	0.75
All food outlets	Zero	1941 (1816-2074)	1344 (1243-1453)	1186 (1105-1273)	844 (776-918)	3055 (2843-3283)	2081 (1911-2267)	243 (220-268)	138 (123-155)
	1-5	1809 (1712-1912)*	1456 (1377-1540)	1121 (1057-1189)	906 (853-962)	2938 (2768-3120)	2247 (2114-2389)	237 (218-257)	165 (151-179)*
	6-10	1857 (1745-1976)	1504 (1416-1598)*	1137 (1065-1215)	948 (889-1012)*	2876 (2688-3076)	2328 (2180-2487)*	235 (214-258)	169 (155-185)*
	11+	1926 (1810-2050)	1394 (1304-1491)	1170 (1095-1250)	873 (813-938)	3048 (2849-3261)	2105 (1956-2265)	246 (224-270)	153 (139-170)
	p-value	0.13	0.06	0.39	0.08	0.39	0.05	0.81	0.01
Modified retail food environment index	Zero	1944 (1819-2077)	1344 (1243-1453)	1187 (1106-1273)	844 (776-918)	3046 (2835-3272)	2081 (1910-2266)	242 (219-267)	138 (123-155)
	FFR+CS[c] only	1819 (1726-1916)*	1469 (1397-1544)*	1123 (1062-1187)	918 (870-969)	2905 (2746-3075)	2248 (2127-2375)	232 (214-250)	164 (152-177)*
	GS[d]: FFR +CS≤0.2	1917 (1808-2032)	1414 (1328-1507)	1176 (1105-1251)	879 (821-941)	3058 (2871-3258)	2154 (2010-2309)	246 (225-268)	162 (148-179)*
	GS: FFR +CS>0.2	1850 (1709-2004)	1491 (1373-1620)*	1118 (1028-1217)	952 (871-1040)*	2868 (2631-3126)	2359 (2155-2583)*	245 (218-276)	162 (143-183)*
	p-value	0.16	0.13	0.29	0.12	0.29	0.12	0.57	0.05

* Statistically different p≤0.05 compared to zero outlets

[a] Adjusted for age (continuous years), race/ethnicity (non-Hispanic black, non-Hispanic white, other), income (<$20,000, $20,001 - $50,000, >$50,000), education level (less than high school, high school graduate, some college, college graduate or more), marital status (never, formerly, or currently married), and study center

[b] GM= geometric mean (95% CI: 95% confidence interval)

[c] FFR+CS= fast food restaurants and convenience stores

[d] GS= grocery stores

Table 5.

Income stratified multivariable adjusted[a] associations between categories of food density within one kilometer of census block group and total caloric intake and daily phosphorous intake with among females with complete income and diet data in the CRIC cohort (n=1889)

Number of outlets within one kilometer		Caloric intake (kcal/day) Income <$20,000	Income $20,000-$50,000	Income > $50,000	Phosphorous (mg/day) Income <$20,000	Income $20,000-$50,000	Income > $50,000
		GM[b] (95% CI)	GM (95% CI)	GM (95% CI)	GM (95% CI)	GM (95% CI)	GM (95% CI)
Fast food	Zero	1291 (1111-1501)	1396 (1237-1575)	1509 (1262-1806)	812 (693-951)	857 (754-974)	946 (774-1157)
	1-3	1574 (1421-1744) *	1338 (1204-1486)	1657 (1396-1967)	965 (866-1075) *	813 (727-909)	1066 (880-1292)
	4-7	1648 (1491-1820) *	1335 (1192-1494)	1640 (1380-1948)	1009 (909-1121) *	842 (747-949)	1070 (881-1298)
	8+	1382 (1214-1573)	1329 (1191-1483)	1731 (1435-2088) *	932 (813-1068)	771 (686-867)	1121 (908-1383) *
	p-value	0.01	0.89	0.21	0.11	0.50	0.12
Grocery stores	Zero	1486 (1365-1618)	1374 (1264-1493)	1647 (1402-1936)	928 (850-1014)	837 (766-914)	1058 (882-1268)
	1	1474 (1319-1647)	1284 (1135-1452)	1656 (1385-1980)	911 (811-1022)	755 (663-860)	1077 (881-1316)
	2+	1767 (1541-2027) *	1309 (1154-1484)	1597 (1314-1941)	1141 (989-1316) *	810 (708-925)	1034 (830-1288)
	p-value	0.04	0.49	0.89	0.01	0.29	0.91
All food outlets	Zero	1351 (1112-1641)	1345 (1181-1530)	1475 (1229-1770)	842 (686-1034)	844 (735-969)	933 (760-1146)
	1-5	1517 (1378-1669)	1408 (1268-1562)	1633 (1377-1936)	939 (849-1039)	838 (750-937)	1050 (867-1272)
	6-10	1696 (1526-1886) *	1286 (1150-1438)	1657(1398-1963)	1030 (921-1152)	813 (722-916)	1084 (895-1311) *
	11+	1377 (1219-1555)	1333 (1198-1484)	1755 (1453-2120) *	917 (807-1042)	786 (701-881)	1110 (898-1373) *
	p-value	0.02	0.56	0.10	0.21	0.76	0.12
Modified retail food environment index	Zero	1350 (1112-1640)	1349 (1186-1535)	1465 (1222-1756)	843 (687-1034)	842 (734-967)	931 (759-1142)
	FFR+CS[c] only	1507 (1378-1648)	1388 (1268-1519)	1720 (1462-2025) *	939 (855-1032)	837 (760-922)	1110 (924-1333) *
	GS[d]: FFR+CS≤0.2	1464 (1313-1631)	1357 (1214-1516)	1599 (1344-1904)	937 (836-1050)	789 (701-889)	1025 (843-1248)
	GS: FFR+CS>0.2	1856 (1604-2147) *	1175 (1013-1362)	1584 (1297-1934)	1120 (961-1305) *	765 (653-896)	1049 (838-1313)
	p-value	0.02	0.21	0.07	0.08	0.60	0.08

* Statistically different p<0.05 compared to zero outlets

[a]Adjusted for age (continuous years), race/ethnicity (non-Hispanic black, non-Hispanic white, other), income (<$20,000, $20,001 - $50,000, >$50,000), education level (less than high school, high school graduate, some college, college graduate or more), marital status (never, formerly, or currently married), and study center

[b]GM= geometric mean (95% CI: 95% confidence interval)

[c]FFR+CS= fast food restaurants and convenience stores

[d]GS= grocery stores

Table 6.

Multivariable adjusted[a] associations between categories of food density within one kilometer of census block group and healthy diet score among participants with complete income and diet data in the CRIC cohort (n=1889)

Number of outlets within one kilometer		**Healthy Diet (Diet score ≥4)**		
		n (%)	**OR[b] (95% CI)**	**p-value**
Fast food	Zero	111 (27.2)	1.0 (ref)	
	1-3	104 (25.5)	0.95 (0.69, 1.29)	0.73
	4-7	108 (26.5)	1.35 (0.97, 1.86)	0.07
	8+	85 (20.8)	1.08 (0.77, 1.51)	0.67
Convenience stores	Zero	188 (46.1)	1.0 (ref)	
	1-2	137 (33.6)	0.92 (0.71, 1.20)	0.55
	3+	83 (20.3)	1.16 (0.84, 1.58)	0.36
Fast food + convenience stores	Zero	103 (25.2)	1.0 (ref)	
	1-4	100 (24.5)	0.73 (0.53, 1.00)	0.05
	5-9	117 (28.7)	1.14 (0.82, 1.60)	0.43
	10+	88 (21.6)	1.00 (0.71, 1.42)	0.99
Grocery stores	Zero	254 (62.2)	1.0 (ref)	
	1	93 (22.8)	1.00 (0.76, 1.32)	0.98
	2+	61 (15.0)	1.11 (0.80, 1.55)	0.52
All food outlets	Zero	99 (24.3)	1.0 (ref)	
	1-5	111 (27.2)	0.70 (0.51, 0.96)	0.03
	6-10	114 (27.9)	1.25 (0.89, 1.76)	0.19
	11+	84 (20.6)	0.93 (0.65, 1.32)	0.69
Modified retail food environment index	Zero	99 (24.3)	1.18 (0.87, 1.60)	0.27
	FFR+CS[c] only	155 (38.0)	1.0 (ref)	
	GS[d]: FFR+CS≤0.2	117 (28.7)	1.25 (0.95, 1.66)	0.12
	GS: FFR+CS>0.2	37 (9.1)	0.81 (0.54, 1.21)	0.30

[a]Adjusted for age (continuous years), gender (male/female), race/ethnicity (non-Hispanic black, non-Hispanic white, other), income (<$20,000, $20,001 - $50,000, >$50,000), education level (less than high school, high school graduate, some college, college graduate or more), marital status (never, formerly, or currently married), and study center; FFR: fast food restaurant; CS: convenience store; GS: grocery store; UF: unhealthy food; HF: healthy food; OR: odds ratio; 95% CI: 95% confidence interval

[b]OR= odds ratio (95% CI: 95% confidence interval)

[c]FFR+CS= fast food restaurants and convenience stores

[d]GS= grocery stores