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Are neighborhood restaurants related to frequency of restaurant meals and dietary quality?: Prevalence and changes over time in the Multi-Ethnic Study of Atherosclerosis

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Abstract

OBJECTIVE: To examine whether density of neighborhood restaurants affected frequency of eating restaurant meals and subsequently affected diet quality.

DESIGN: Cross-sectional and longitudinal designs. Restaurant density within three miles of participant addresses was linked to their Healthy Eating Index (HEI 2010, derived from a food frequency questionnaire) and frequency of eating restaurant meals. Using structural equation models, analyses adjusted for socio-demographics, select health conditions, region, residence duration, and area-level income.

SETTING: Urbanized areas in multiple regions of the U.S., years 2000–2002 and 2010–2012.

PARTICIPANTS: Participants aged 45-84 were followed for 10 years (N=3567).

RESULTS: Median HEI was 59 at baseline and 62 at follow-up. Residing in areas with a high density of restaurants (highest ranked quartile) was cross-sectionally associated with 52% higher odds of frequently eating restaurant meals (≥3 times/week, odds ratio [OR]: 1.52, 95% confidence interval [CI] 1.18-1.98) and 3% higher odds of having lower dietary quality (HEI lowest quartile<54, OR:1.03, CI: 1.01-1.06). Longitudinal changes were small and associations not sustained. Cross-sectional analysis found 34% higher odds of having lower dietary quality for those who frequently ate at restaurants (OR: 1.34,CI:1.12-1.61); and more restaurant meals (over time increase ≥1 times/week) was associated with higher odds of having worse dietary quality at follow-up (OR: 1.21,CI:1.00-1.46).

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CONCLUSIONS: Restaurant density was associated with frequently eating out in cross-sectional and longitudinal analyses but was associated with lower dietary quality only in cross-sectional analyses. Frequent restaurant meals were negatively related to dietary quality. Interventions that encourage less frequent eating out may improve population dietary quality.

Keywords

food environment; food away from home; restaurant meals; diet; structural equation models

1. INTRODUCTION

There have been exponential increases in availability and consumption of prepared foods [1, 2]. Relative to meals at home, restaurant foods tend to be larger in portion size and higher in sodium, saturated fat and cholesterol, and lower in fiber[3-5]. Among adults, eating fast foods has been associated with lower overall dietary quality[6, 7] and frequency of fast-food restaurant meals has been directly associated with lower quality diet[8]. The growth of sit-down restaurants has occurred alongside fast-food/fast-casual restaurants[9, 10] and chains dominate the full-service restaurant industry, capturing 70% of market share [11]. A number of studies have documented that the dietary quality of most sit-down restaurant meals is as-low or even lower than fast-food/fast-casual restaurants[4, 5, 12].

Research investigating neighborhood conditions on health posits that environments offering many opportunities for eating out make it more convenient to eat out[1, 13]. Thus, density of neighborhood restaurants may be associated with higher frequency of eating restaurant meals and subsequently worse dietary outcomes among adults (Figure 1). Findings that directly link neighborhood restaurants to dietary quality have been mixed[14] and most studies focused only on youth or young adults[15]. Among mid- to older-aged adults, most studies reported no evidence of an overall association[8, 16-19] but there have been exceptions[18]. Work by Burgoine et al (2016) found that fast food density within 1 mile of residence was cross-sectionally associated with more consumption of foods that are typically found in fast-food establishments (pizza, burgers, and deep-fried foods).

Reasons for null or mixed results in studies of mid- to older-aged adults could include a number of factors including measurement issues such as inadequacy in the way neighborhood restaurant density was defined (only fast food[8, 19] or only fast food chains[17], data were limited to one or two regions[17, 18, 20], and/or limitations of dietary assessment and operationalization (for example, only energy and a few macro-nutrients[16, 17, 19] rather than a full dietary score). Importantly, most studies have not explored intervening mechanisms on the pathway from restaurant exposure to dietary quality. For example, frequency of eating restaurant food is presumed to be an intermediary between restaurant environment and diet but is rarely considered.

The current study examined the association between restaurant density, frequency of eating restaurant meals, and dietary quality in a multi-ethnic cohort of mid- to older-aged adults. The cross-sectional hypothesis was that participants with higher exposure to restaurants will have more frequent restaurant meals and lower dietary quality. The longitudinal hypothesis was that having worse dietary quality over time will be higher for participants who eat out more frequently and reside in areas where there were increases in restaurant density.

2. METHODS

2.1 Data

Data came from The Multi-ethnic Study of Atherosclerosis (MESA), a population-based longitudinal cohort study. MESA's main objective was to determine the characteristics of subclinical cardiovascular disease and its progression. The study recruited ethnically diverse adults aged 45–84 years with no known presence of cardiovascular disease. Individuals were recruited from six sites across the United States: Bronx/Upper Manhattan, NY; Baltimore City and Baltimore County, Maryland; Forsyth County, North Carolina; Chicago, Illinois; St. Paul, Minnesota; and Los Angeles County, California. Each site recruited participants from locally available sources (lists of residents, list of dwellings, telephone exchanges) as well as publicizing the study in local media. Sampling and recruitment procedures have been described in detail elsewhere[21]. MESA included a baseline examination (2000–2002) and four follow-up exams. Exam 5 data were collected approximately 10 years after baseline (2010 to 2012). Analyses were limited to baseline and exam 5 because dietary data were only collected in exams 1 and 5. Written informed consent was obtained from the participants, and the study was approved by institutional review boards at each site (according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants).

2.2. Diet

Diet was assessed via a Food Frequency Questionnaire (FFQ). The FFQ was a modified Block-style, 128 item questionnaire. Participants were asked about their usual eating habits over the past 12 months. For each of the food items on the FFQ, respondents chose their consumption frequency (rare or never, 1 per month, 2–3 per month, 1 per week, 2 per week, 3–4 per week, 5–6 per week, 1 per day, and 2+ per day). Their frequency of consumption was then weighted by a multiplier, according to their reported typical serving size (× 0.5, × 1.0, and × 1.5 for small, medium, and large, respectively). The MESA FFQ was adapted from the questionnaire designed for the Insulin Resistance and Atherosclerosis Study (IRAS)[22], and has been described elsewhere[23]. Modifications to the FFQ included additional items to reflect the multi-ethnic composition of the MESA cohort. IRAS was validated against 24 hour dietary recalls[22], and the MESA diet data correlated as expected with high-density lipoprotein (HDL) cholesterol and triacylglyceride (TAG) concentrations[24], and cardiometabolic conditions[25-29].

Total energy was calculated for each FFQ line item using the Nutrition Data System for Research (NDS-R database; Nutrition Coordinating Center, Minneapolis, MN, USA).[24] Following work by others, we excluded participants whose dietary data were considered unreliable, due to reporting usual energy intake <600 or >6000 kcal[24] (approximately 6% of the participants who completed the dietary questionnaire).

2.2.1 Outcome: Healthy Eating Index (HEI)—
We used the Healthy Eating Index version 2010, to assess dietary quality. It reflects 2010 U.S. federal Dietary Guidelines, has been used to monitor and assess diet quality in the United States[30-32], and has (1) adequate content validity[30], (2) sufficient construct validity, and (3) acceptable reliability[33]. It includes twelve components: total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acid, refined grains, sodium, and empty calories. Each component contributes a minimum of 0 to a maximum of 5, 10, or 20 points, resulting in a range of 0 to 100 for the total score; higher scores indicate a healthier diet[30]. Linkage of MESA food consumption with HEI food composition was done following the protocol established by the National Cancer Institute[30, 34]. Each individual's nutritional values were derived by linking the food items from the FFQ to MyPyramid Equivalents Database version 2.0 (MPED), multiplying by the number of servings reported in the FFQ, summing to obtain a value for each component in the HEI, and then calculating the HEI score.

In the cross-sectional analysis, the HEI at exam 5 was divided into quartiles of the observed HEI distribution (range 11.67 -- 89.56) with the lowest quartile hereafter referred to as a "lower quality diet" (<54.28). In longitudinal analysis, each participant's HEI at exam 5 was subtracted from exam 1 (resulting in range −44.50 -- 42.40) and then divided into quintiles with the lowest quartile hereafter referred to as "worse diet quality over time " (<−6.19). The rationale for using within-sample ranking of dietary data is that it acknowledges the low precision inherent in dietary self-reports[35]. Numerous studies have used ranked values to define unhealthy or healthy diets (for example[36-38]) because it differentiates lower and higher values within a sample without relying on an absolute threshold of dietary quality.[39]

2.2.2 Mediator: Frequency of restaurant meals—
"Frequency of restaurant meals" (an intermediate variable in the causal pathway between neighborhood food environment and healthy eating) was determined by a single question in the FFQ: "how many times per week do you eat at restaurants for meals?". In the cross-sectional analysis, *frequency of restaurant meals* was operationalized as a binary indicator: being in the top quartile at exam 5 (≥3 times per week) or not. In longitudinal analysis, *higher frequency of restaurant meals* was a within-person change indicator: a binary indicator: ≥1 more time per week relative to exam 1 (≥1 more time per week is approximately the top 25% of the sample).

2.3. Neighborhood-level Exposures

Addresses of MESA participants and addresses of restaurant establishments were used to link participants to the density of restaurants near their residence. Restaurant establishment data originated from Dun and Bradstreet and was compiled/cleaned for the National Establishment Time Series database.[40, 41] Restaurant density was derived in GIS by computing a three-mile (4.8 kilometers) kernel density of food establishments around each MESA participant's home. Using a kernel density resulted in a distance-weighted density such that restaurants furthest from the participant's residence were weighted less than those closest to the residence[42]. A three-mile kernel radius was chosen because it aligns with empirical findings of average distances to food shopping[43, 44] and roughly aligns with what others have done[45, 46] thus enabling comparability across studies. The measure represents density to all restaurants and includes fast food, sit-down restaurants, and other eating places; drinking establishments that only served alcohol were excluded. The correlation was very high between total restaurants and subgroups of restaurants, thus analyses will only be shown for total restaurants (for example total restaurants and fast-food restaurants spearman rank correlation ≥0.92). Further, combining all restaurants mitigated mis-classification of restaurants by type and reduced the number of participants with zero exposure to restaurants.

In the cross-sectional analysis, *high density of restaurants* was operationalized as the highest ranked quartile of restaurants at exam 5 (≥16 restaurants within 3 miles of each participant's residential address). In longitudinal analysis, *change in restaurant density* represented a relatively stable value or an increase in density (−0.6 to +69.8 restaurants within 3 miles, top 25% of the sample). We included relatively stable density in this group because preliminary analyses showed that almost all participants experienced a decrease in restaurant density over time.

2.4. Covariates

Person-level covariates were age, sex, race/ethnicity, education level, household income/wealth (combination of income level and ownership of four assets: car, home, land, and investments), and years lived outside the US (classified into none vs >0); see variable classifications shown in Table 1. Additional covariates were: self-reported general health status (poor or fair vs. good to excellent, only available at baseline), and body mass index (BMI). Additional area-level information was derived from participants' address: census region (northeast, mid-west, south, and west) and percent of households with higher incomes (per capita household income >$50,000). Census region was included because diet and restaurant outlets are known to vary by region. Longitudinal control variables also included change variables: change in per capita income (exam 5-exam 1), change in area income (exam 5-exam 1); and categorical variables representing region at exam 1, region at exam 5, and moved outside of baseline county. The list of variables is in Table 3 footnote.

2.5. Analytic Sample

Out of a total 6814 participants enrolled at baseline, 4716 participated in exam 5 (69% of the exam 1 sample). We excluded those without the following data elements: neighborhood food environment data (N=13), dietary components at exam 1 and/or exam 5 (N=851), frequency of restaurant meals (N=78) and key covariate information (N=207). Finally, 3567 (53% of 6814 participants) were retained for analyses.

Sample characteristics for included vs. excluded participants were similar by age and sex but included participants had higher income and education, fewer Black/African-American, and slightly lower restaurant density around their residence (data not shown).

2.6 Statistical Analyses

As described above, restaurant density (exposure) and restaurant meals (mediator) were transformed into ranked categorical variables and the variable represented the top ranked categories (highest density of restaurants and highest restaurant meals) vs. not top ranked.. The reasons for this classification were: 1. both variables were skewed thus transforming to a categorical variable aided interpretation. 2. preliminary analyses found non-linearity in the association (for example, there was only a discernable effect between restaurant density and diet for the upper rank). Further, for the change analyses, on average there was little change over time in these exposures thus we needed to maximize change by selecting the highest increase. We only show binary variables to facilitate interpretation of results in structural equation modeling (the method becomes is overly complex to interpret when operationalized with multi-category exposures/mediators).

Cross-sectional analyses limited the dataset to exam 5. The rationale for using exam 5 rather than exam 1 in cross-sectional analysis is that there was more heterogeneity in exposure at exam 5 because participants relocated to other areas during follow-up.

2.6.1. Structural equation modeling—We used a structural equation model (SEM). The conceptual framework specified that the causal pathway between density of food environment and healthy eating is through the indirect (mediation) effect of frequency of restaurant meals. There is no plausible reason why density of local restaurants would affect diet directly not via restaurant meals thus we did not model a direct causal effect of density of food environment on poor dietary quality.

Adjusted analysis (presented in Table 3) present results for pathway 1, the direct effect between high restaurant density and high frequency of restaurant meals; pathway 2: the direct effect between high frequency of restaurant meals and low or worse dietary quality; and the combination of pathway 1 and 2: the total effect of restaurant density on dietary quality. The analyses only had one sequence/pathway, and thus the total effect is also the 'total indirect effect' which tests whether the effect of restaurant density on dietary quality was mediated by frequency of restaurant meals. Standard errors for the test were generated via bootstrapping (based on 1000 resamples, with replacement).

We implemented the SEM in M-plus 8.3(47). Maximum Likelihood Estimation was used to estimate the model parameters. We chose this estimator in M-plus as it can accommodate binary outcomes, binary mediators and permit the evaluation of indirect (mediation) effects via logit regression.(48)

Goodness-of-fit statistics were used to assess whether the structure of the model was appropriate for the data. Logistic regression has limited options for assessing SEM fit and lacks external target values to indicate acceptable fit. Thus, we used the probit distribution to assess fit because it is able to generate standard fit statistics available for a Gaussian distribution. We employed a group of well-known fit indices to evaluate the model fit: Chi-square to degree of freedom ratio (χ^2/df), Standardized Root Mean Square Residual (SRMR), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). Goodness-of-fit in SEM indicates the degree of agreement between the model-implied covariance matrix and the covariance matrix of the observed data(49). If these two covariance matrices are close, then the model fits the data well. (see Table 3 footnotes)

2.6.1.1. Adjustment variables: Models adjusted for confounding by socio-demographics: age, sex, race, education, income/wealth categories, general health, body mass index, ever having lived outside the U.S., region of residence, whether they moved residence during follow-up, and area-level income (details are in Table 3 footnotes). Adjustment was achieved by allowing for direct paths between sociodemographics and exposure, sociodemographics and mediator, and sociodemographics and outcome.

2.6.1.2. Sensitivity analyses: Sensitivity analysis used nested model comparisons (AKA multiple-group analysis [(50)]) to test interactions between restaurant density and the following variables: population density (below median, at or above median), sex (male vs. female), income/wealth index (low to middle vs. high), movers (moved since baseline vs. not), and obesity (obese vs. not obese).

We examined sensitivity of the cross-sectional results to operationalizing dietary quality as a continuous variable. Successful interpretation of mediation results requires consistency in the directionality (signage) of the pathways [(51)]. For this reason, we reverse coded dietary quality so that higher values would signify worse diet. (Note that we did not examine continuous variables for restaurant density and frequency of restaurant meals due to these variables being highly skewed. Further, we did not operationalize change in diet as a continuous variable as there was very little longitudinal change in diet, thus would not be able to detect a signal in our data.)

We used the longitudinal data and tested the inverse of our main hypothesis: whether a *decline* in restaurant density was associated with *less* eating out; and *less* eating out was associated with *better* diet. In order to align with variable operationalization used in the main analyses, 'decline in restaurant density' was defined as the lowest quartile (loss of at least 7 restaurants within a 3 mile area), 'less eating out' was at least 2 times less per week (relative to exam 1), and 'improved dietary quality' was defined as highest quintile of change in HEI score.

3. RESULTS

3.1. Descriptive results

Participant socio-demographics at baseline (exam 1) and exam 5 (approximately 10 years later) are reported in Table 1. At baseline, mean age was 60.2 (STD 9.6), slightly more than one-half sample was non-White, 58.3% had less than a college degree, and 31.4% had obesity. Approximately one-half of participants lived in areas where median per capita income was at or above the US median (≥$50,000,[(52)]).

Diet (HEI and restaurant meals)—Median HEI was 59.3 at baseline (similar to the U.S. average[(53)]) and rose slightly by exam 5 (median 61.6, 25th-75th percentile 54.4 to 67.2) (Table 2). Participants ate out approximately 2 times per week at baseline (median 2, 25th to 75th percentile 1 to 4) and the frequency declined slightly by exam 5 to 1 time per week (median 1, 25th to 75th percentile 1 to 3).

Restaurants—At baseline, participants lived in areas with a median of 9 restaurants in their area (25^{th}-75^{th} percentile [25-75pctile] 4.8-23.3 in the 3-miles surrounding the participant's home). Median and 25-75pctile in 3-miles was 2.10 (25-75pctile 1.29-4.00) for fast food and was 4.71 (25-75pctile 1.03-12.03) for non fast-food. At follow-up, residents lived nearby slightly fewer restaurants (median −1.8 fewer restaurants). Over the follow-up period, 30% moved residence. Most of the movers stayed within the same region/county but moved to less densely populated areas (where there were fewer restaurants). Population density was highly correlated with restaurant density (spearman rank correlation 0.85, data not shown).

3.2. Adjusted results

Table 3 displays cross-sectional (Panel A) and longitudinal (Panel B) adjusted results. In cross-sectional analyses, high restaurant density was associated with more eating out and worse dietary quality. Relative to areas with fewer restaurants, residing in an area with many restaurants (top quartile, ≥16 restaurants within 3 miles) was directly associated with 52% higher odds of eating out frequently (≥3 times per week, OR: 1.52, 95% CI 1.18, 1.98). In turn, frequent eating out was directly associated with 34% higher odds of having lower dietary quality (OR: 1.34, 95% CI 1.12, 1.61).

Results suggest that frequency of eating out was a mediator in the pathway between restaurant density and diet (total indirect effect P-value 0.02). Relative to areas with fewer restaurants, residing in an area with many restaurants was associated with 3% higher odds of having lower dietary quality (HEI 1st quartile, OR: 1.03, 95% CI 1.01, 1.06).

In longitudinal analysis, relative to exam 1, residing in areas with a stable or increase in restaurants was not associated with more restaurant meals and was not associated with worsening of dietary quality. There was no evidence that frequency of eating out was a mediator between restaurant density and diet (total indirect effect P-value 0.87). Nonetheless, relative to exam 1, results suggested that more restaurant meals over time (increase of ≥1 times per week) was associated with 21% higher odds of having worse dietary quality although the confidence interval included the null value (OR: 1.21, 95% CI 1.00, 1.46).

3.3. Sensitivity analyses

There was no evidence of cross-sectional interactions between restaurant density and population density (below median, at or above median), sex (male vs. female), income/wealth index, movers (moved since baseline vs. not), and obesity (obese vs. not obese); all P for interaction ≥0.2.

Cross-sectional inference was unchanged when a continuous variable was used for dietary quality (as described in methods, results not shown in tables). Frequent eating out was directly associated with 1.48 lower (worse) HEI score (β 1.48, 95% CI 0.77, 2.20). Results suggested that frequent eating out was a mediator in the pathway between restaurant density and worse diet (total indirect effect P-value 0.007). Relative to areas with fewer restaurants, residing in an area with many restaurants was associated with 0.15 lower HEI score (β 0.15, 95% CI 0.04, 0.27).

Changes were very small in restaurant density, eating out, and diet thus longitudinal interactions were not tested; and continuous dietary change was not examined. However, we used the longitudinal data to test the inverse of our main hypothesis: whether a decline in restaurant density was associated with less eating out; and less eating out was associated with better diet. Under this hypothesis, the regression parameter estimates were in the expected direction but all results were null (results not shown). Thus, longitudinal inference was largely unchanged except that pathway 2 (is less eating out associated with better diet?) was null. We conjecture that pathway 2 was null because the hypothesis followed the overall temporal trend of the data (on average participants ate out less and dietary quality improved over time) thus making it harder to detect a signal in our dataset.

4. DISCUSSION

4.1 Summary

This study of residents in select urbanized areas across the U.S., found that mid-aged/older adults living in an area with many restaurants was associated with more restaurant meals and lower dietary quality. However, those findings were only apparent in cross-sectional data. When we examined changes in restaurant environment and changes in diet quality, there was no association between restaurant density and restaurant meals or between restaurant density and dietary quality. The impacts of frequent restaurant meals on dietary quality was more robust. Frequent restaurant meals was associated with much higher odds of having lower dietary quality in cross-sectional data and the relationship persisted in longitudinal analyses (despite confidence intervals including the null value).

Distinct advantages of this study are described here. 1. We included cross-sectional and longitudinal data and participants who resided in many urbanized areas across the U.S.. Almost all prior studies used cross-sectional data, and many were limited to a single state/ province (for example[17, 19], limiting generalizability of the findings). 2. While aggregating restaurants into all restaurant types presented some limitations to our analyses (discussed in Limitations section), there were also strengths in this approach. By combining all restaurants, restaurant-type misclassification was not an issue. Further, in the U.S., research has found dietary quality and obesigenic potential of most sit-down restaurant meals is roughly equivalent or worse than fast-food/fast-casual restaurants[4, 5, 12]. Whereas, the literature on the effect of restaurant density on dietary outcomes among mid-older adults has almost exclusively examined fast-food density and reported null findings[8, 17, 19]. 3. We incorporated two causal pathways into the same model: i. the pathway between restaurant density and restaurant meals; and ii. the pathway between restaurant meals and dietary quality. The advantage of simultaneously modeling these pathways -- and adjusting for potential socio-demographic confounding of both pathways – is that we were able to explicitly model the associations of interest. Despite weak results for the total effect of restaurant density and dietary quality, our results suggested that frequent restaurant meals is linked to lower dietary quality and that restaurant density may be positively related to more restaurant meals. Below, we discuss these findings in the context of the literature.

4.2 Pathway 1+2: restaurant density and diet

Prior studies that aimed to quantify the direct association between the restaurant density and diet focused mostly on youth or young adults and reported mixed results[15]. Among mid- to older-aged adults, cross-sectional data reported no evidence of an overall association between GIS-assessed fast food density and dietary intake[8, 16-19]. The exception was a study conducted in one UK county that found a positive cross-sectional association between fast food outlet density and total grams of foods commonly associated with fast-food establishments (pizza, burgers, and deep-fried foods).[18] The UK study used different measures from ours making comparisons difficult. Nevertheless, our cross-sectional findings aligned with the UK study: that restaurant density could promote an unhealthy diet. However, the magnitude of the association we found was small: the top quartile of restaurant density was associated with 3% higher odds of having a lower quality diet. Further, the association did not persist when we examined changes in restaurant density and changes in diet over a 10 year period.

4.3. Pathway 1: restaurant density and frequency of restaurant meals

Most studies that assessed the association between restaurant density and frequency of eating restaurant food among adults used cross-sectional data from a single province/ state, and results were mixed. Some found expected associations between higher density of restaurants and frequency of restaurant meals[8, 54] or higher relative spending on away-from-home foods.[55] However, other studies did not find evidence of an association([20, 45, 56]. Literature that relied on a single study site/region and focused only on fast-food tended to show null results[20, 45, 56] whereas multi-site/multi-region studies [8] and/or including non-fast-food restaurants [54] tended to report expected results. Results from our cross-sectional adjusted analyses aligned with studies that found positive associations. We found residing in an area with many restaurants (≥16 restaurants of all types within 3 miles) was associated with 52% higher odds of frequent restaurant meals (≥3 times per week) relative to residing in areas with fewer restaurants. However, no association was observed when longitudinal data were used (with the caveat that quantification of longitudinal effects was hampered by the fact that -- on average -- changes in density and frequency of restaurant meals were very small). Our null longitudinal results aligned with overall null results reported in the only longitudinal study to date[46].

4.4. Pathway 2: restaurant meals and diet quality

Prior work reported that fast-food and full-service restaurant food consumption among adults was associated with significant increases in lower overall dietary quality[6-8] and nutritional biomarkers[57]. Our study aligned with those results. Frequent restaurant meals was cross-sectionally associated with 34% higher odds of having lower dietary quality; and relative to exam 1, on average, those who increased their frequency of restaurant meals (increase of ≥1 times per week) had 21% higher odds of worse dietary quality. This pathway had the strongest signal among the pathways examined likely due to being most proximal to dietary decision making.

4.5. Limitations

Below, we note a few study limitations and steps taken to reduce their impact. *(1)* The limitations of FFQ data are well-known[58] and FFQs are not well-suited for looking at individual dietary components thus we only used the HEI. Nevertheless, the face validity of the FFQ used in this study has been documented[22, 24] and the instrument was designed to include many foods that reflect the diversity of a multi-ethnic population. Further, we confirmed that the sample distribution of dietary measures calculated for our study (HEI and frequency of restaurant meals) roughly aligned with distributions reported in external datasets (surveillance datasets and other research[53, 59, 60]). Additionally, we utilized within-sample ranking of dietary data (quartile or quintile) which differentiated lower and higher values within a sample without relying on an absolute threshold of dietary quality.[39] *(2)* It is unknown whether MESA participants utilized restaurants within three miles of their residences; however, three-miles aligned with the average distance individuals travel for food[61, 62] and distances associated with dietary outcome examined in another restaurant study[46]. We did not have information on the work location of participants however, our cohort is older and most were not employed by exam 5. *(3)* In our sample, the correlation was very high between total restaurants and subgroups of restaurants, thus we were not able to determine if results differed by restaurant type or diversity of restaurant types. *(4)* Some of the analyses were cross-sectional which are subject to temporal biases. Further, there were only two exam periods for the diet data which limited our options for longitudinal analyses. Our older sample was quite stable in their residences and showed only small changes in diet and residential exposures over 10 year period; this hampered our ability to detect hypothesized signals from the longitudinal data. *(5)* General health status was not available at the follow-up exam. Controlling for age will account for some of the changes in health over time, nevertheless residual confounding could remain. *(6)* Finally, results are not likely generalizable to younger populations who tend to have higher frequency of restaurant meals and worse overall dietary quality[15, 63].

4.6. Conclusions

While higher restaurant density may contribute to neighborhood walkability promote walking among older adults[64] or provide opportunities for social interaction for older adults living alone[65], this current study focused on restaurant density's negative impact on dietary outcomes. With a large proportion of the U.S. population not meeting national dietary guidelines, it is important to understand distal and proximal risk factors for lower quality diets. This study affirmed that eating frequent restaurant meals had a negative association with dietary quality, thus reiterating an important public health message that is poorly understood by consumers[66]: in general, restaurant meals are not healthier than preparing food at home and can be associated with worse dietary quality[63, 67, 68]. Our findings also suggested that restaurant density may encourage eating more restaurant meals likely due to residents' having many opportunities for eating out thus making it more convenient to eat out[1, 13]. Our findings suggested that restaurant density linkages to dietary quality may occur via frequency of restaurant meals thus, interventions aimed at consumers to limit the frequency of eating out may be a strategy for improving dietary quality.

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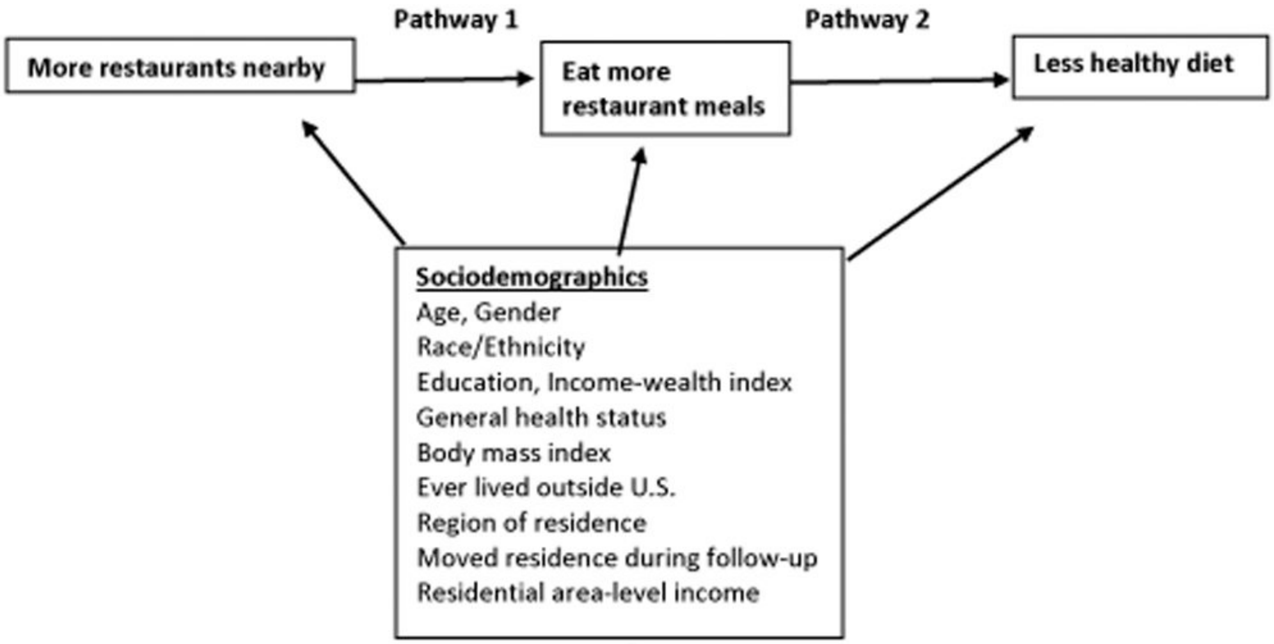

Figure 1.
Conceptual framework: illustration of pathways between restaurant density and diet

Table 1.

Participant characteristics, N=3567 *

	Exam 1 (2000-03)	Exam 5 (2010-2011)
Sociodemographic characteristics		
Age, mean (STD)	60.2 (9.6)	69.6 (9.5)
Gender		
Male, %	47.6	---
Race /Ethnicity		
White (Caucasian), %	44.4	---
Chinese-American, %	10.7	---
Black, African-American, %	24.3	---
Hispanic or Latino, %	20.6	---
Education		
Completed HS/GED or less, %	29.2	---
Some college, Technical or Associate degree, %	29.1	---
Bachelor's degree or higher, %	41.7	---
Income-wealth index †		
Low, %	9.5	7.9
Middle, %	39.1	43.0
High, %	51.4	49.1
General health status		
Fair or poor, %	7.4	---
Body mass index (weight, kg /height, m^2)		
Normal (<25), %	29.3	29.1
Overweight (25-<30), %	39.3	37.5
Obesity (>=30), %	31.4	33.4
Ever lived outside U.S.		
Yes, %	26.2	---
Region of residence		
Midwest, %	37.7	36.4
Northeast, %	16.7	16.5
South, %	30.4	31.4
West, %	15.2	15.7
Moved residence during follow-up		
Did not move, %	---	69.9
Moved within the same county, %	---	21.2
Moved out of the county, %	---	8.9
Residential area-level income		
Percent of household living in areas at or above US median income (≥$50,000), %		
Mean (STD)	42.7 (17.6)	51.2 (18)

[*]The analytical sample includes 3567 participants. Out of a total 6814 participants enrolled at baseline, 4716 participants were retained in Exam 5. We further excluded (a) 13 participants with missing neighborhood food environment data; (b) 851 participants with missing dietary information in both exams; (c) 78 participants with missing eating out information in both exam 1 and exam 5; and (d) 207 participants with missing covariates.

[†]Income-wealth index is participant's inflation adjusted annual per capita inflation-adjusted household income (5-levels)+wealth index. Wealth is home ownership+car ownership+land ownership+investments. In preliminary analyses, generalized additive models were used to assess non-linearity and data were subsequently classified into low <2, medium 2-<6, high >=6.

Table 2.

Distribution of the Healthy Eating Index, frequency of restaurant meals, and restaurant density, at baseline and follow-up, N=3567*

		Exam 1 (2000-03)	Exam 5 (2010-2011)
Baseline and follow-up values			
Health Eating Index (HEI-2010)			
Mean (STD)		58.9 (9.3)	60.4 (10)
Median value (25th-75th percentile)		59.3 (52.8 - 65.6)	61.6 (54.4 - 67.2)
Frequency of restaurant meals, number of times per week			
Median value (25th-75th percentile)		2 (1 - 4)	1 (1 - 3)
0-<2 times per week, %		43.5	51.8
>=2 times per week, %		56.5	48.2
Restaurant density within 3-mile buffer (all restaurants includes fast food and other eating places)			
Median value (25th-75th percentile)		9 (4.8 - 23.3)	6.8 (3.4 - 16)
Change variables (continuous)			**Change Exam 5 – Exam 1**
Change in Healthy Eating Index			
	Range (minimum - maximum)		−44.5 - 42.4
	Median value (25th-75th percentile)		1.39 (−4.57 - 8.03)
Change in frequency of restaurant meals, per week			
	Range (minimum - maximum)		−9 - 9
	Median value (25th-75th percentile)		0 (−1 - 0)
Change in restaurant density in 3 mile buffer			
	Range (minimum - maximum)		−226.5 - 69.85
	Median value (25th-75th percentile)		−1.8 (−0.6 - −6.7)

*The analytical sample includes 3567 participants. Out of a total 6814 participants enrolled at baseline, 4716 participants were retained in Exam 5. We further excluded (a) 13 participants with missing neighborhood food environment data; (b) 851 participants with missing dietary information in both exams; (c) 78 participants with missing eating out information in both exam 1 and exam 5; and (d) 207 participants with missing covariates.

Table 3.

Adjusted odds of having worse dietary quality and frequently consuming restaurant meals, in response to residing in areas with more restaurants (N = 3567)

	Pathway 1			Pathway 2			Pathway 1 and Pathway 2		
	Direct effect			Direct effect			Total indirect effect *		
	O.R.	95% C.I.	p-value	O.R.	95% C.I.	p-value	O.R.	95% C.I.	p-value
PANEL A †. Cross-sectional results, exam 5									
	Outcome A-1 Frequent restaurant meals (4th quartile, ≥3 times per week)			**Outcome A-2** Lower dietary quality (1st quartile of Healthy Eating Index)					
High restaurant density (top quartile, ≥16 restaurants within 3 miles vs. fewer restaurants)									
	1.52	1.18, 1.98	0.009	---	---	---	1.031	1.01, 1.06	0.02
High frequency of restaurant meals (top quartile, ≥3 times per week vs. less eating out)									
	---	---	---	1.34	1.12, 1.61	0.007	---	---	---
PANEL B ‡. Change results, exam 1 to 5									
	Outcome B-1 Increased frequency of restaurant meals (approximately 4th quartile, ≥1 times per week).			**Outcome B-2** Worse diet quality at follow-up (lowest change quintile 1 indicating worsening dietary quality)					
Stable or increase in restaurant density (top quartile of change, −0.6 to +69.8 restaurants witdin 3 miles vs. fewer restaurants over time)									
	0.99	0.81 1.22	0.94	---	---	---	1.00	0.99, 1.01	0.87
Increase in restaurant meals (top quintile, ≥1 more time per week relative to exam 1 vs. stayed same or less eating out over time)									
				1.21	1.00, 1.46	0.08	---	---	---

*The 'total indirect effect' P-value tested whether the effect of restaurant density on dietary quality was mediated by frequency of restaurant meals. The analysis only had one sequence/pathway, and thus the 'total indirect effect' is also the 'total effect'. Standard errors for the test were generated via bootstrapping (based on 1000 resamples, with replacement).

†**PANEL A Cross-sectional results, exam 5**. Outcome A-1 shows the odds of frequent restaurant meals (4th quartile, ≥3 times per week). Outcome A-2 shows the odds of worse dietary quality (1st quartile of Healthy Eating Index). Adjustment variables were: linear splines for age (younger, and older), gender, race/ethnicity, education, income-wealth, ever lived outside U.S., general health status, BMI categories, region, area income is high. Model fit indices from a Probit model were: Chi-square=1.25, df = 1, P-value = 0.26, Comparative Fit Index (CFI) = 1, Tucker-Lewis Index (TLI) = 0.987, Root Mean Square Error of Approximation (RMSEA) = 0.008, Standardized Root Mean Square Residual (SRMR) = 0.004

‡**PANEL B Change results, exam 1 to 5.** Outcome B-1 shows the odds of increase in restaurant meals (approximately 4th quartile, ≥1 more time per week relative to exam 1). Outcome B-2 shows the odds of a having worse diet quality at follow-up (lowest change quintile 1 indicating worsening dietary quality). Adjustment variables were: linear splines for age (younger, and older), gender, race/ethnicity, education, income-wealth at exam 1, change in per capita income (exam 5-exam 1), region at exam1, region at exam 5, area income is high at exam 5, change in area income is high, ever lived outside U.S, and moved outside of baseline county. Model fit indices from a Probit model were: Chi-square: 1.606, df = 1, p-value = 0.205, RMSEA = 0.013, CFI = 0.998, TLI = 0.884, SRMR = 0.004.