RESEARCH ARTICLE

Association of food environment and cardiovascular mortality

[version 1; peer review: 1 approved with reservations, 1 not approved]

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Abstract

Background: The association between healthy dietary habits and cardiovascular health is well established; however, it is unknown whether access to healthy and sustainable food sources correlates with better cardiovascular mortality.

Methods: County-level data on Food Environment Index (FEI) for 2014 was retrieved from the County Health Rankings dataset. County-level data on cardiovascular diseases (CVD) mortality was obtained from the death registry files of the National Vital Statistics System. We used a linear regression model to assess the association between FEI and CVD mortality after adjusting for sex and race distributions, urban-rural distribution and median household income.

Results: Data were available for 3069 counties. The mean FEI was 7.0 (SD, 1.2) and mean CVD mortality (per 100,000 population) was 252.7 (95% CI, 247.1-258.3) across the United States in 2014. There was a significant inverse association between FEI and adjusted CVD mortality ($P < 0.001$). Every unit increase in FEI corresponded to a decline in CVD mortality of 19.1 per 100,000 population.

Conclusions: Higher FEI correlates with reduced CVD mortality. Improving access to healthy sustainable food sources may help decrease cardiovascular mortality.

Keywords

Cardiovascular, mortality, food

Open Peer Review

Approval Status ? X

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Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the **Agriculture, Food and Nutrition** gateway.

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Introduction

In the United States, approximately 23.5 million Americans lack access to sustainable food sources like supermarkets¹. This disparity in food environment has been shown to markedly affect the cardiovascular diseases (CVD) risk factors in a population². However, data regarding the association of the food environment with cardiovascular diseases mortality rate remains unknown. Previous studies have investigated the association between access to food and CVD risk^{2,3}. However, these studies were not nationally representative and lacked the focus on the association between the food environment and CVD mortality. With an extremely high burden of cardiovascular mortality in the United States⁴, quantifying the association between food environment and CVD mortality rates at the national level can help appraise the disparity in food environment across the United States and can give critical information on how it relates to CVD mortality rates. Such an effort can assist policymakers to generate knowledge and allocate resources to mitigate the burden of cardiovascular diseases.

We sought to assess the association of food environment and cardiovascular mortality rate at the county level across the United States.

Methods

County-level data on the Food Environment Index (FEI) for the year 2014 was retrieved from the County Health Rankings and Roadmaps dataset⁵. FEI is a standardized measure that calculates the food environment by accounting for limited access to a grocery store or supermarket, consistency of availability of food, and the burden of cost. FEI equally weighs 'limited access to food' and 'food insecurity' as the two indicators for the food environment. 'Limited access to food' is defined as the percentage of the population in a county that is low income and does not live close to a grocery store. Living in close proximity to a grocery store is defined as living less than 10 miles from a grocery store in rural areas and less than a mile in non-rural areas. This measure also includes low-income status, which is defined as having an annual family income of $\leq 200\%$ of the federal poverty threshold for the family size⁶. The second indicator, 'food security,' represents a lack of constant access to the food supply and is defined as the percentage of the population who did not have access to a reliable source of food during the past year. We created a two-stage fixed-effects model to develop this measure using information from the Community Population Survey, Bureau of Labor Statistics, and the American Community Survey⁵. FEI ranges from 0 to 10, with 0 representing the worst and 10 the best possible food environment rating, respectively.

Data on county-level age-standardized CVD mortality rates were retrieved from National Vital Statistics System, the details of which have been previously published⁷. Counties were identified using their Federal Information Processing Standard (FIPS) codes, which are numerical values unique to every county. These unique identifiers were used to extract the county-level mortality data, matching for the corresponding FEI from the County Health Rankings dataset.

A linear regression model was employed to determine the association of FEI with county-level age-standardized CVD mortality rates after adjusting for the following variables - sex, race, urban-rural distribution, educational level (defined as the percentage of the population who graduated some form of college), percentage of uninsured population under the age of 65 years, and percentage of adults smokers in the county. These data elements were obtained from 2010 US Census Bureau's Census Population Estimates data and Behavioral Risk Factor Surveillance System data of 2014^{8,9}.

Further, we stratified the counties according to their FEI values and compared 100 counties with the highest FEI with 100 counties with the lowest FEI. Socio-economic demographic characteristics and surrogate markers for healthy dietary practices (prevalence of obesity and diabetes) were then compared amongst the two groups. These data elements were available in the County Health Rankings and Roadmaps dataset. Obesity was defined as the percentage of the population with a BMI $\geq 30\text{kg/m}^2$, and diabetes was assessed using the response to the question, "Has a doctor ever told you that you have diabetes?" Women with reported gestational diabetes mellitus were not included because the gestational diabetes mellitus is a distinct transient illness with different characteristics and entails different disease trajectories than diabetes. Analysis was conducted using R programming language version 3.6.0¹⁰.

Results

Data were available for 3069 counties. Mean FEI across the United States was 7.0 (SD, 1.2). Nationally, the mean CVD mortality rate (per 100,000 population) was 252.7 (95% CI, 247.1-258.3) in 2014. Per our analysis, FEI was inversely associated with CVD mortality rate, with a 19.1% decrease in CVD mortality rate for every unit increase in FEI (Figure 1). At the county level, FEI had a significant inverse association with the adjusted CVD mortality rate; adjusted for sex distribution, race distribution, urban-rural distribution, percentage of uninsured population under the age of 65 years, education attainment, and percentage of adult smokers in this analysis ($P < 0.001$ and $\beta = -3.6$).

The CVD mortality was 310.9 per 100,000 population (95% CI, 295.8-326.0) in counties with lowest FEI compared to 225.6 per 100,000 population (95% CI 218.7-232.6) in counties with the highest FEI. This difference accounted for a 27.4% relative risk reduction in CVD mortality rates between the two county groups. There was no significant difference seen in the mean age and sex distribution between the two groups. However, the counties with the highest FEI had a larger White population than counties with lower FEI (Table 1). Furthermore, the prevalence of obesity and diabetes was significantly higher in counties with lowest FEI when compared to the counties with the highest FEI; 34.4% vs. 28.1% for obesity, and 14.6%, and 8.7% for diabetes ($P < 0.001$).

Discussion

Our study shows a significant association between FEI and CVD mortality rate. Higher FEI is associated with lower

Figure 1. Association of food environment index and cardiovascular mortality at county level. Cardiovascular mortality in deaths per 100,000 population.

Table 1. Characteristics of counties with highest and lowest food environment index.

	Counties with highest food environment index (n=100)	Counties with lowest food environment index (n=100)	P value
CVD mortality	225.6 (95% CI 218.7 - 232.6)	310.9 (95% CI, 295.8 - 326.0]	<0.001
Mean FEI (SD)	9.1 (0.3)	3.2 (0.9)	<0.001
Demographics % [mean(SD)]			
Age	40.5 (4.6)	38.9 (7.0)	0.06
Female	50.0 (1.3)	49.6 (3.6)	0.34
White	80.4 (17.0)	51.1 (26.3)	<0.001
Black	4.8 (5.2)	30.2 (30.3)	<0.001
Population living in rural areas	46.6 (34.5)	77.4 (28.0)	<0.001
Uninsured population	22.0 (4.9)	12.0 (4.4)	<0.001
Annual household income (\$USD)	73136.1 (17865.1)	35036.8 (7419.3)	<0.001
Percentage of adult smokers	15.1 (2.1)	22.2 (5.3)	<0.001
Percentage of adults reporting no leisure physically activity	23.5 (4.3)	30.5 (5.0)	<0.001
Morbidity % [mean(SD)]			
Obesity	28.1 (4.0)	34.4 (6.2)	<0.001
Diabetes	8.7 (1.5)	14.6 (3.3)	<0.001

CVD, cardiovascular diseases; FEI, food environment index; SD, standard deviation; CI, confidence interval; USD, United States Dollars.

cardiovascular mortality rate. Furthermore, counties with the lowest FEI had a greater prevalence of obesity and diabetes compared to counties with the highest FEI. Our results provide an assessment of how disparities in access to nutritious food

and food insecurity may affect population health outcomes. To our knowledge, this is the first study of its kind that evaluates the association between food environment and CVD mortality rate at the national level.

This study supplements existing literature in many ways. Prior studies have shown an association of healthy dietary habits with better cardiovascular health^{11–13}. Further, Kelli *et al.* showed that people living in areas with low access to nutritious food are more likely to have an unfavorable cardiovascular risk profile than people living in areas with better access². This argument has been explored by other studies as well, which found that access to poor quality food sources, such as convenience stores, is associated with lower quality diets³. However, the impact of the food environment on the cardiovascular mortality rates remained unexplored. In our analysis, we found an inverse association between access to food sources and cardiovascular mortality rates. These results underscore the potential benefit of targeting and improving FEI to improve the CVD mortality rates.

The food environment has been shown to be associated with cardiovascular health^{14,15}. We found that counties with the lowest FEI had a greater prevalence of obesity and diabetes in comparison to counties with the highest FEI. This may, in part, be due to increased dependence on processed fast foods on which the populations with the lowest FEI rely on in the absence of a supermarket or other nutritious food sources¹⁶. Hence, decreasing barriers to access nutritious and reliable food sources may be an important step towards improving cardiovascular mortality. Future studies are needed to explore this association in a prospective design with longitudinal follow-up. Nevertheless, identifying areas with low food accessibility and diverting resources to these ‘high risk’ hotspots may aid in decreasing this disparity in the food environment and may help improve overall cardiovascular health. Furthermore, efforts should be directed in subsidizing nutritious food options as an incentive for our population to adopt better dietary practices and combat CVD.

Our study has the following limitations. Firstly, due to the analysis design, we cannot ascertain a direct causal effect between FEI and CVD mortality. However, we accounted for

sociodemographic factors across a large sample size and observed a significant correlation between FEI and CVD mortality rate. Secondly, our study is a socio-demographically adjusted population-based study. Hence, patient-level direct risk factors were not included in our analysis. However, sociodemographic factors play a critical role in assessing cardiovascular health at the population level¹⁷. Thirdly, while the food insecurity takes both proximities to nutritious foods and income into account, it does not account for access to or use of food assistance benefits among eligible families. Finally, we could not account for the health status data as an adjustment covariate in our model. Given the county-level health status data is not available, this represents a future prospect for studies investigating the food environment and CVD mortality.

In conclusion, higher FEI is associated with lower cardiovascular mortality rates. These findings support broad-based interventions to reduce existing disproportion in access to nutritious and reliable food sources in order to minimize the burden of cardiovascular mortality in the United States.

Data availability

Source data

Data can be accessed through the 2014 County Health Rankings and Roadmaps dataset (<https://www.countyhealthrankings.org/>), National Vital Statistics System (<https://www.cdc.gov/nchs/nvss/index.htm>), the 2010 US Census Bureau (<https://www.census.gov>) and 2014 Behavioral Risk Factor Surveillance System (<https://www.cdc.gov/brfss/index.html>).

Code availability

Source code is available from: <https://github.com/suveenangraal/CountyHealth>

Archived source code at time of publication: <https://doi.org/10.5281/zenodo.3871947>¹⁰

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Current Peer Review Status: ? ✖

Version 1

Reviewer Report 28 June 2021

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Maria Gabriela M. Pinho

Department of Epidemiology and Data Science, Amsterdam Public Health Research Institute, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

Introduction:

The introduction is too superficial and it seems to be lacking relevant references. In addition, some of cited literature is not accurate. For example, in the sentence "Previous studies have investigated the association between access to food and CVD risk", the authors cite the work of Rummo *et al.* 2015. However, this work analysed the relationship between the food environment and diet quality, not CVD risk.

The rationale for the study is also not clearly elaborated. How exactly would the understanding on the association between food environment and CVD mortality help in the assessment of the disparity in food environment across the United States?

Methods:

The authors mention that the FEI was collected from the County Health Rankings and Roadmaps dataset. However, more details about this data source is needed. For example, what data was used to calculate 'limited access to food' and 'food insecurity'?

Please describe this "two-stage fixed effects model" in more detail. And did you test if multilevel modelling was needed? - e.g. was there clustering at county level?

It is not clear how CVD mortality rate was measured. From figure 1, CVD mortality seems to range from 0 to 550, what does it mean?

Stratified analyses and comparison of FEI groups according to obesity and diabetes is a surprise here. There should be a rationale for this in the introduction, and this should be mentioned as additional aims of the study.

Figure 1:

This relationship does not seem to be linear. I wonder if the authors tested the assumptions for a

linear regression before performing this type of model? This is not mentioned in the methods section. If assumptions are not met, other modelling methods should be performed.

Also, it is not clear from this figure that “there was a 19.1% decrease in CVD mortality rate for every unit increase in FEI (Figure 1)”.

Table 1:

Physical activity appears in this table, but no mention is made in the methods section. Was it account for in your models?

Conclusion:

Conclusions seem to be supported by the results. However, I have concerns about the methodology and if statistical analyses are appropriated for this type of data.

Is the work clearly and accurately presented and does it cite the current literature?

No

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

No

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology, Nutrition, Food environment

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 15 July 2020

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Javier Valero-Elizondo

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Jhaveri & Krishnan *et al.* present a short but impactful manuscript, where they studied the relationship between food environment and cardiovascular mortality, using various national-level sources. The current manuscript is clearly written, with an appropriate analysis plan and with the conclusions being adequately supported by the presented results. Jhaveri & Krishnan *et al.* arrived at the conclusion that a higher (i.e. more favorable) food environment index was associated with lower cardiovascular mortality. Both 'limited access to nutritious food sources' and 'food insecurity' are becoming important topics both on public health policy and cardiovascular disease epidemiology research circles. This is an important contribution to the scientific literature, delivering a timely message that can potentially have a direct effect on individuals from lower income levels, who are already at a higher risk of cardiovascular disease. I do, however, have a few comments:

Major comments:**Introduction:**

1. Line 11: It appears that the authors are trying to convey the importance of their aim: study the relation of food environment and CVD mortality, which can certainly inform different stakeholders, from healthcare all the way to public health policy. The issue that I see is that this sentence is redundant, stating the intended goal, and repeating itself as it ends. I would recommend rephrasing this sentence, especially in light of the Introduction being as succinct.

Methods:

2. I am not quite sure I understand what 'measure' was created by the two-stage fixed-effects model. Could the authors elaborate on this section? I understand this is the method used by the County Health Rankings – did the authors create their own?
3. Could the authors explain what methodology or criteria were used to identify/select the variables included in the linear regression model for FEI and CVD mortality rates? In addition, I understand that lack of insurance is especially important in the population younger than 65 years of age due to lack of Medicare – but does this mean that insurance status was collected for all ages, and "uninsured" (among those < 65 years of age) was the variable included in the model? Or was the study population only individuals < 65 years of age? This is not clear.
4. Seeing as they are related to CVD mortality, were other CV risk factors available to inform the current analysis (hypertension, for example)? It would be interesting to see, especially for hypertension, since close to 50% of US adults have hypertension, and many treat it with lifestyle modifications, with diet and exercise at their center – which would be germane to the topic at hand and would add another level of relevance, without necessarily adding complexity to the analysis.
5. Related to the comment above: I notice that "leisure physical activity" is included in Table 1

of the results, but is not mentioned in the Methods or Results sections. Was this intended?

Discussion:

6. In the Limitations section specifically, the second limitation brings some confusion. On the one hand, I understand that the study was “socio-demographically adjusted, population-based”, but then the authors mention that patient-level direct risk factors were not included in the analysis. Could the authors expand on this area? I am not entirely clear which risk factors belong in this section, seeing that some were used (e.g. smoking, diabetes and obesity), and some were not (e.g. physical activity, or potentially, hypertension).

Minor comments:

Abstract:

1. Background: I wouldn't utilize the phrasing “*better* cardiovascular mortality”. Perhaps “lower cardiovascular mortality” or “improved mortality outcomes”?

Keywords:

2. It is standard practice that keywords be listed alphabetically.

Introduction:

3. “United States” appears 3 times in a 1-paragraph Introduction. I would suggest using the “US” acronym after defined the first time, to avoid repetitiveness in such a small space (even beyond the Introduction, at the authors' discretion).
4. I notice that “cardiovascular mortality” and “CVD mortality” are used interchangeably at different times. For the sake of consistency, I would recommend choosing one and using throughout, which would reflect greatly on the authors in terms of their order, methodology, and attention to detail (once more, even beyond the Introduction, at the authors' discretion).

Methods:

5. The paper would benefit greatly from a short sentence depicting the study population, and exclusion/inclusion criteria.
6. Items like food insecurity are often asked at a family level, and in the current manuscript, it seems like results are reported per capita. Is there any information that the authors could provide as to the actual measurement of the FEI individual components, and how they were estimated? If allowed by word count.
7. Typo: a space is needed between the words “was” and “conducted” in the last line of the Methods section.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Outcomes research, public health, cardiovascular disease prevention and epidemiology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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