Association of food environment and cardiovascular mortality
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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
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Introduction

In the United States, approximately 23.5 million Americans lack access to sustainable food sources like supermarkets\(^1\). This disparity in food environment has been shown to markedly affect the cardiovascular diseases (CVD) risk factors in a population\(^2\). 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\(^3\). 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 States\(^4\), 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 dataset\(^5\). 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 size\(^6\). 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 Survey\(^7\). 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 published\(^8\). 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\(^9\).

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 \(\geq 30\) 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 3.6.0\(^10\).

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...
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.

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

<table>
<thead>
<tr>
<th></th>
<th>Counties with highest food environment index (n=100)</th>
<th>Counties with lowest food environment index (n=100)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CVD mortality</strong></td>
<td>225.6 (95% CI 218.7 - 232.6)</td>
<td>310.9 (95% CI, 295.8 - 326.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Mean FEI (SD)</strong></td>
<td>9.1 (0.3)</td>
<td>3.2 (0.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Demographics % [mean(SD)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>40.5 (4.6)</td>
<td>38.9 (7.0)</td>
<td>0.06</td>
</tr>
<tr>
<td>Female</td>
<td>50.0 (1.3)</td>
<td>49.6 (3.6)</td>
<td>0.34</td>
</tr>
<tr>
<td>White</td>
<td>80.4 (17.0)</td>
<td>51.1 (26.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Black</td>
<td>48.5 (5.2)</td>
<td>30.2 (30.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Population living in rural areas</td>
<td>46.6 (34.5)</td>
<td>77.4 (28.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Uninsured population</td>
<td>22.0 (4.9)</td>
<td>12.0 (4.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Annual household income ($USD)</td>
<td>73136.1 (17865.1)</td>
<td>35036.8 (7419.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Percentage of adult smokers</td>
<td>15.1 (2.1)</td>
<td>22.2 (5.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Percentage of adults reporting no leisure physically activity</td>
<td>23.5 (4.3)</td>
<td>30.5 (5.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Morbidity % [mean(SD)]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>28.1 (4.0)</td>
<td>34.4 (6.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>8.7 (1.5)</td>
<td>14.6 (3.3)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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

**Figure 1. Association of food environment index and cardiovascular mortality at county level.** Cardiovascular mortality in deaths per 100,000 population.
This study supplements existing literature in many ways. Prior studies have shown an association of healthy dietary habits with better cardiovascular health\(^1\). 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 access\(^2\). 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 diets\(^3\). 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\(^4\). 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 sources\(^5\). 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 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 level\(^6\). 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**


**Code availability**

Source code is available from: https://github.com/suweenangraal/CountyHealth

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

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**References**


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