Original Research
Food Insecurity is Associated With COPD Morbidity and Perceived Stress

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Running Head: Food Insecurity in COPD

Keywords: chronic obstructive pulmonary disease; food insecurity; social determinants of health

Abbreviations: SES: Socioeconomic status COPD: Chronic obstructive pulmonary disease CURE COPD: Comparing Urban and Rural Effects of Poverty on COPD Study; FEV₁: Forced expiratory volume in the first second; FVC: Forced vital capacity; HFIAS: Household Food Insecurity Access Scale; CAT: COPD Assessment Test; mMRC: modified Medical Research Council; SGRQ: St. George’s Respiratory Questionnaire; HADS: Hospital Anxiety and Depression Scale; PSS: Perceived Stress Scale; IRR: Incident rate ratio

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This article has an online supplement.
Abstract

Background: Low socioeconomic status (SES) has been associated with worse clinical outcomes in chronic obstructive pulmonary disease (COPD). Food insecurity is more common among individuals with low SES and has been associated with poor outcomes in other chronic illnesses, but its impact on COPD has not been studied.

Methods: Former smokers with spirometry-confirmed COPD were recruited from low-income areas of Baltimore, Maryland and followed for 9 months as part of a cohort study of diet and indoor air pollution. Food insecurity and respiratory outcomes, including COPD exacerbations and patient-reported outcomes, were assessed at regular intervals. The association between food insecurity and COPD outcomes was analyzed using generalized linear mixed models. Additional analyses examined the association of COPD morbidity with sub-domains of food insecurity and the association of food insecurity with measures of psychological wellbeing.

Results: Ninety-nine participants had available data on food insecurity and COPD outcomes. 26.3% of participants were food insecure at one or more times during the study. After adjusting for individual SES, neighborhood poverty, and low healthy food access, food insecurity was associated with higher incidence rate of moderate and severe exacerbations, worse dyspnea, COPD health status, and respiratory-specific quality of life. Sub-domains of food insecurity were independently associated with worse patient-reported outcomes. Food insecurity was additionally associated with higher perceived stress.

Discussion: Among former smokers with COPD, food insecurity was associated with higher incidence of exacerbations, worse patient-reported outcomes, and higher perceived stress. Sub-domains of food insecurity were independently associated with worse patient-reported outcomes.
Introduction

Social determinants of health, such as socioeconomic status (SES), economic instability, and exposure to indoor and outdoor pollutants, have a significant impact on the health of individuals with chronic obstructive pulmonary disease (COPD), including higher prevalence of COPD and worse COPD outcomes. Among the mechanisms by which SES may contribute to health disparities, there is increasing evidence regarding the contribution of dietary factors to respiratory health among individuals with COPD. Specifically, adverse dietary patterns, often common in low SES settings, such as diets high in processed and calorie-dense foods but deplete in nutrients or diets low in omega-3 fatty acid intake have been linked to COPD morbidity. Food insecurity, or the lack of consistent access to enough food for an active, healthy life, is among the factors than can impact health among low SES individuals. However, its role in respiratory health in COPD is unclear.

Food insecurity has been associated with cardiometabolic conditions such as hypertension, diabetes, and coronary heart disease in large cross-sectional studies, as well as development and poor control of diabetes in longitudinal studies. Possible mechanisms by which food insecurity may impact COPD morbidity include poor dietary quality as well as psychological factors such as stress, anxiety, and depression, which have been associated with food insecurity and separately with COPD morbidity. Furthermore, since 2007, food insecurity has more than doubled among older adults in the U.S., the population with the highest prevalence of COPD. In spite of this, limited research has examined whether there is an association between food insecurity and COPD outcomes.
We sought to evaluate the association between food insecurity and COPD morbidity among individuals enrolled in the urban arm of the Comparing Urban and Rural Effects of Poverty on COPD (CURE COPD), a prospective cohort study assessing the impact of air pollution and diet on low-income COPD patients residing in Baltimore. We additionally sought to evaluate the possible association of food insecurity with measures of psychological wellbeing.

Methods

Study population and study design

Participants were longitudinally followed as part of an observational cohort of former smokers studying the impact of diet and indoor air pollution on COPD, with clinic visits at baseline, 3 months, and 6 months and with monthly telephone interviews for the six month study period and additional three months thereafter. Eligible participants were aged 40 or older with physician-diagnosed moderate-to-severe COPD based on spirometry test (post-bronchodilator FEV₁/FVC < 0.7 and FEV₁ % predicted < 80%), a smoking history of >10 pack-years, and residing in census tracts with poverty rate above 10% (see Online Supplement for detail). Exclusion criteria are available in the online supplement. Participants were recruited via several methods: (1) a database of participants from prior studies who indicated interest in participation in future studies; (2) recruitment from clinics, including direct physician referral, messages to patients with desired ICD codes, and pulmonary clinic patients who had signed waivers for research contact; (3) flyers posted in outpatient clinics and community locations; (4) social media, newspaper, and radio advertisements; and (5) referral from existing study participants. The study
protocols were reviewed and approved by the Johns Hopkins School of Medicine IRB, and written informed consent was obtained from all participants prior to any data collection.

**Demographic and socioeconomic data**

Demographic data, including self-reported race, household income, and educational attainment were obtained via questionnaire at baseline. Information on neighborhood characteristics were obtained via geocoded address at baseline. Limited neighborhood food access was defined as an area where at least a third of people live more than 0.5 miles from the nearest supermarket, supercenter, or large grocery store in urban areas (or more than 10 miles in case of rural areas). Neighboring poverty rate represented the percentage of all families in a census-tract with annual income below the federal poverty rate.

**Food insecurity assessment**

The Household Food Insecurity Access Scale (HFIAS) is a validated metric used for measuring a household-level state of “food security” – defined as a state in which “all people [in the household] at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life”. The instrument consists of 18 questions: 9 questions on occurrence (yes/no), with each having a single follow-up questions on frequency—that assess whether households are food secure or insecure based on a participant’s 30-day recall of his/her household experience (see Online Supplement for detail). For our study, the HFIAS questionnaire was administered by trained staff at each clinic visit – baseline, 3-month, and 6-month.
Along with the overall food insecurity measure, three subdomains of the HFIAS were also explored: 1) anxiety and uncertainty about food supply, 2) insufficient food quality, and 3) insufficient food intake and its physical consequences.

**Respiratory outcomes**

Validated respiratory outcome measures were assessed by trained staff longitudinally at each clinic visit. Medication use was assessed by participant self-report via questionnaire. Health status was assessed with the COPD Assessment Test (CAT),\textsuperscript{21} dyspnea was assessed with the modified Medical Research Council (mMRC) scale,\textsuperscript{22} and respiratory-specific quality of life was assessed with the St. George’s Respiratory Questionnaire (SGRQ).\textsuperscript{23} In addition, exacerbation data was prospectively monitored over nine months with monthly telephone interviews. Moderate exacerbations were defined as an unscheduled doctor’s visit, antibiotic or systemic steroid use, or treatment in an urgent care facility due to COPD related illness. Severe exacerbations were defined as any COPD-related emergency room visit or hospitalization. Spirometry was performed according to the American Thoracic Society protocol (Koko spirometer; nSpire) at each study visit.

**Assessment of psychological wellbeing**

Symptoms of depression and anxiety were assessed at each visit via the 14-question Hospital Anxiety and Depression Scale (HADS)\textsuperscript{24} which has two subscales, HADS-Anxiety (HADS-A) and HADS-Depression (HADS-D). Stress was assessed via the Perceived Stress Scale (PSS), a 10-item self-report questionnaire designed to measure “the degree to which individuals appraise situations in their lives as stressful”.\textsuperscript{25}
Statistical Analysis

Baseline participant characteristics were summarized using mean (SD) or median (IQR) for the continuous variables and frequency (%) for the categorical variables. Due to a large majority of participants reporting as food secure at each visit (~85%), the primary analysis used HFIAS as a categorical indicator with two categories: food secure at all times or ever food insecure during the study period. Per guidelines, the dichotomous indicator (secure vs insecure) was constructed for each subdomain of the HFIAS food insecurity indicator, and similar to the overall indicator, the indicators were operationalized to represent the summary measure of the study period within each domain (secure at all times vs. ever insecure).

To assess the associations between respiratory morbidity and food insecurity, we conducted linear regression of continuous COPD outcomes on dichotomous food insecurity, using generalized linear mixed models to account for the repeated measures, adjusted for covariates. For the total frequency of exacerbations across the study period, negative binomial regression of exacerbations was conducted with the dichotomous indicator of food insecurity and the participant’s total follow-up days as an offset, adjusted for covariates in the parsimonious and primary models. The parsimonious model included individual factors of baseline age, gender, race, smoking pack-years, BMI, comorbidity count, controller medication use, FEV1 % predicted based on Global Lung Function Initiative race-neutral spirometry equation. The primary model included all covariates of the parsimonious model and added the individual and neighborhood SES factors of educational attainment, household income, neighborhood poverty rate, and limited neighborhood food access.
As secondary analyses, we repeated the main regression of COPD morbidity with the subscales of the HFIAS: 1) anxiety and uncertainty about food supply, 2) insufficient food quality, and 3) insufficient food intake and its physical consequences, and separate regression analyses were run for each. We further explored the association of food insecurity with depressive and anxiety symptom scores (HADS-D/A) and perceived stress scale as secondary outcomes. 25

Missing observations for covariates were few and were imputed using sample means. All analyses were conducted with Stata/IC 15.1 software (StataCorp, College Station, Texas); and statistical significance criteria was set at p<0.05.

Results

Study population characteristics

A total of 116 individuals were recruited into the study, with 17 withdrawing before all baseline data could be collected. Ninety-nine individuals completed the baseline visit between 2016 and 2021 and had available data regarding food access and respiratory morbidity, which comprises the entire urban cohort of the CURE COPD study. The average age of the study population was 66.4 years, 55% of participants were female, and 41% were white (Table 1). Participants had smoked an average of 46.3 pack-years and the mean FEV1 percent predicted was 49.8. Approximately half of participants (49%) had educational attainment of high school education or less, and two-thirds (66%) had an annual household income of less than $30,000, representing an overall low income population.

26.3% of participants were ever food insecure during the study. Of those individuals reporting food insecurity, 12 (46%) reported anxiety and uncertainty about household food
supply, 26 (100%) reported insufficient food quality, and 13 (50%) reported insufficient food intake with physical consequences. Compared to participants that were always food secure, participants who were ever food insecure were younger (61 vs 68 years old), more likely to report depressive or anxiety symptoms (42% vs 22%), and had higher perceived stress.

Associations between food insecurity and COPD morbidity

In the parsimonious model, adjusting for baseline demographic and clinical factors, food insecurity was associated with higher incidence rate of moderate and severe exacerbations during the study period (IRR=2.2, p=0.031). Food insecurity was also associated with worse COPD health status (higher CAT score: β=2.7, p=0.044), dyspnea (higher mMRC score: β=0.5, p=0.002), and respiratory-specific quality of life (higher SGRQ score: β=6.4, p=0.039) (Table 2).

In the primary model, after additionally adjusting for individual SES, neighborhood poverty and low healthy food access, the association of food insecurity with respiratory outcomes was robust. Specifically, food insecurity continued to be associated with higher incidence rate of moderate and severe exacerbations during the study period (IRR=2.4, p=0.014). Food insecurity was also associated with worse dyspnea (higher mMRC score: β=0.5, p=0.001), COPD health status (higher CAT score: β=2.8, p=0.040), and respiratory-specific quality of life (higher SGRQ score: β=6.6, p=0.031) (Table 2; Figure 1).

Secondary Analyses

Among sub-domains of food insecurity, reported insufficient food quality was associated with all measured outcomes, including higher incidence rate of moderate and severe
exacerbations during the study period and worse CAT, mMRC and SGRQ. Reported insufficient food intake was associated with patient reported outcomes of worse CAT and mMRC scores (Table 3; Figure 1). Anxiety and uncertainty about food supply were associated with worse CAT and SGRQ scores.

In the parsimonious model, food insecurity was associated with increased depressive symptoms, increased anxiety symptoms, and increased perceived stress (Table 4). This association remained robust for perceived stress after adjustment for individual and neighborhood SES factors and neighborhood food access in the primary model ($\beta=3.3$, $p=0.029$), although the association of depressive symptoms and anxiety symptoms with food insecurity was no longer statistically significant.

**Discussion**

This prospective observational study of urban, low-income former smokers with COPD demonstrates an association between food insecurity and respiratory morbidity. Specifically, those reporting food insecurity during the study had an increased incidence of moderate and severe COPD exacerbations and worse dyspnea, COPD health status, and respiratory-specific quality of life. These findings add to the growing body of literature regarding social determinants of health and COPD morbidity and mechanisms by which socioeconomic disadvantage worsens COPD outcomes.

There are numerous mechanisms by which SES can impact respiratory health, including increased exposure to indoor and outdoor pollution as well as lack of access to health care.\(^1\,\(^2\,\(^9\)\) Among these multiple possible mechanisms, the current study provides evidence that food insecurity has an independent association with COPD morbidity. Even when adjusting for other
markers of SES, including education level, individual and neighborhood income, and neighborhood access to healthy food, food insecurity continues to have a significant association with exacerbations and patient reported outcomes.

Analyses of the subdomains of food insecurity and measures of psychological wellbeing support a complex influence of food insecurity on respiratory morbidity in COPD (Figure 2). Levels of perceived stress have been shown to increase risk of healthcare utilization among individuals with COPD,15 and stress may directly influence COPD pathophysiology through chronic inflammation.30 The state of food insecurity and anxiety surrounding it may impact symptoms. Indeed, the subdomain of food insecurity related to anxiety and uncertainty about food supply was associated with worse health status and quality of life. Furthermore, perceived stress was significantly associated with food insecurity.

Additionally, the subdomain of food insecurity related to food quality was associated with increased exacerbation rates and worse patient reported outcomes. This suggests that the actual quality of diet plays a direct role in COPD morbidity independent of the stress of food insecurity or the other mechanisms of socioeconomic health disparities. Low quality diets as assessed via the Alternative Healthy Eating Index, characteristic of low intakes of fruit, vegetables, omega-3 fatty acids and whole grains, have been shown to be associated with an increased risk of developing COPD.9,31–33 Similarly, “Western” diets high in refined grains, red and processed meats, and soft drinks have been associated with respiratory morbidity including prevalence of COPD.34 In addition to overall dietary quality, specific nutrient intakes have also been associated with respiratory disease. In particular, diet quality may impact respiratory health through antioxidants and anti-inflammatory mediators such as omega-3 fatty acids,35,36 which may reduce the chronic inflammation that is the hallmark of COPD progression.37–39
Among the strengths of this study is the extensive clinical and socioeconomic data collected on participants. This allows of differentiation of the various possible mechanisms by which socioeconomic status and comorbidities may influence COPD outcomes. The study population is enriched for low-income individuals living in an urban environment and accordingly is representative of the specific challenges of such an environment. For instance, the percentage of participants reporting food insecurity within a 6-month period (26%) was substantially higher than the national rate of food insecurity during a given year (10%).\textsuperscript{40} The small size of the study and specific socioeconomic inclusion criteria could limit the overall generalizability of the study but emphasizes the importance of social determinants of health in this population. Finally, while analysis of food insecurity subdomains suggests diet quality could play a direct role in COPD morbidity, further studies with measures of general diet quality are needed to determine the role of diet quality in COPD.

Conclusion

This study of former smokers with COPD living in urban Baltimore found a significant association between food insecurity and respiratory morbidity. Individuals who experienced food insecurity during the study had higher incidence of moderate or severe COPD exacerbations and worse health status, dyspnea, respiratory-specific quality of life, and perceived stress. These associations persisted even when adjusting for other socioeconomic factors such as education level as well as individual and neighborhood income and neighborhood food access. Additionally, subdomains of food insecurity were individually associated with respiratory morbidity. These findings suggest that food insecurity may be one of the contributors to socioeconomic disparities in COPD.
Acknowledgements


Declaration of Interest

Daniel Belz reports grants from NIH/NHLBI and the American Lung Association and grants and personal fees from Insmed Incorporated

Nirupama Putcha reports grants from NIH/NIEHS and NHLBI and personal fees from Regeneron and GSK

Ashraf Fawzy reports grants from NIH/NHLBI and personal fees from Regeneron during the conduct of the study

Meredith McCormack reports grants from NIH/NHLBI and personal fees from GSK

Michelle Eakin reports grants from NIH/NHLBI

Nadia Hansel reports grants from NIH, EPA, and COPD Foundation, grants and personal fees from AstraZeneca, grants and personal fees from GSK, grants from Boehringer Ingelheim, and personal fees from Mylan
References


17. Leung CW, Wolfson JA. Food Insecurity Among Older Adults: 10-Year National Trends and Associations with Diet Quality. Published online 2021. doi:10.1111/jgs.16971


Table 1. Baseline Participant Characteristics, Mean (SD) or N (%)

<table>
<thead>
<tr>
<th>Demographics &amp; Individual Risk Factors</th>
<th>All (N=99)</th>
<th>Food Secure* (N=73)</th>
<th>Food Insecure* (N=26)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, Yrs</td>
<td>66.4 (8.2)</td>
<td>68.1 (7.6)</td>
<td>61.4 (8.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender, N (% Female)</td>
<td>55 (55.6%)</td>
<td>42 (57.5%)</td>
<td>13 (50.0%)</td>
<td>0.507</td>
</tr>
<tr>
<td>Race, N (% White)</td>
<td>41 (41.4%)</td>
<td>31 (42.5%)</td>
<td>10 (38.5%)</td>
<td>0.722</td>
</tr>
<tr>
<td>Smoking Pack-years</td>
<td>46.3 (30.5)</td>
<td>43.3 (28.1)</td>
<td>54.7 (35.7)</td>
<td>0.100</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>32.3 (8.4)</td>
<td>31.5 (7.8)</td>
<td>34.5 (9.8)</td>
<td>0.125</td>
</tr>
<tr>
<td>Comorbidity Burden, Count</td>
<td>3.8 (2.1)</td>
<td>3.9 (2.2)</td>
<td>3.6 (1.6)</td>
<td>0.454</td>
</tr>
<tr>
<td>Controller Medication Use [ICS/LABA/LAMA], N (% Yes)</td>
<td>72 (72.7%)</td>
<td>53 (72.6%)</td>
<td>19 (73.1%)</td>
<td>0.963</td>
</tr>
<tr>
<td>FEV1 % Predicted</td>
<td>49.8 (16.6)</td>
<td>50.2 (16.2)</td>
<td>48.7 (18.0)</td>
<td>0.689</td>
</tr>
<tr>
<td>Individual SES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational Attainment [Some college or above], N (%)</td>
<td>50 (50.5%)</td>
<td>38 (52.1%)</td>
<td>12 (46.2%)</td>
<td>0.605</td>
</tr>
<tr>
<td>Annual Household Income</td>
<td></td>
<td></td>
<td></td>
<td>0.246</td>
</tr>
<tr>
<td>&lt;$30,000</td>
<td>66 (66.7%)</td>
<td>47 (64.4%)</td>
<td>19 (73.1%)</td>
<td></td>
</tr>
<tr>
<td>=$30,000</td>
<td>26 (26.3%)</td>
<td>22 (30.1%)</td>
<td>4 (15.4%)</td>
<td></td>
</tr>
<tr>
<td>Refuse to answer/Don't know</td>
<td>7 (7.1%)</td>
<td>4 (5.5%)</td>
<td>3 (11.5%)</td>
<td></td>
</tr>
<tr>
<td>Neighborhood SES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Families in Census Tract below Poverty Line</td>
<td>18.4 (12.5)</td>
<td>18.3 (13.4)</td>
<td>18.7 (9.8)</td>
<td>0.901</td>
</tr>
<tr>
<td>Food Access, N (% Living in Limited Food Access Census Tract)</td>
<td>64 (64.6%)</td>
<td>48 (65.8%)</td>
<td>16 (61.5%)</td>
<td>0.699</td>
</tr>
<tr>
<td>Psychological Wellbeing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressive/Anxiety Symptom, N (% Yes)</td>
<td>27 (27.3%)</td>
<td>16 (21.9%)</td>
<td>11 (42.3%)</td>
<td>0.045</td>
</tr>
<tr>
<td>Perceived Stress Scale</td>
<td>12.9 (6.4)</td>
<td>11.9 (6.2)</td>
<td>15.8 (6.0)</td>
<td>0.006</td>
</tr>
<tr>
<td>Food Insecurity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFIAS Food Insecurity, Continuous</td>
<td>0.7 (2.0)</td>
<td>0.0 (0.0)</td>
<td>2.5 (3.2)</td>
<td></td>
</tr>
<tr>
<td>HFIAS Food Insecurity [Ever Food Insecure], N (%)</td>
<td>26 (26.3%)</td>
<td>0 (0%)</td>
<td>26 (100%)</td>
<td></td>
</tr>
<tr>
<td>Anxiety &amp; Uncertainty about the Household Food Supply</td>
<td>14 (14.1%)</td>
<td>2 (2.7%)</td>
<td>12 (46.2%)</td>
<td></td>
</tr>
<tr>
<td>Insufficient Food Quality</td>
<td>27 (27.3%)</td>
<td>1 (1.4%)</td>
<td>26 (100%)</td>
<td></td>
</tr>
<tr>
<td>Insufficient Food Intake &amp; Its Physical Consequences</td>
<td>13 (13.1%)</td>
<td>0 (0%)</td>
<td>13 (50.0%)</td>
<td></td>
</tr>
</tbody>
</table>

**“Food secure” represents those who were food secure across all visits, “Food insecure” represents those who were food insecure at any point during the study.**
### Table 2. Association between Food Insecurity and COPD Morbidity

<table>
<thead>
<tr>
<th></th>
<th>Model 1 (Parsimonious)</th>
<th>Model 2 (Primary)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiratory symptoms</strong> a</td>
<td>Mean Difference</td>
<td>P</td>
</tr>
<tr>
<td>CAT</td>
<td>2.7 (0.1, 5.3)</td>
<td>0.044</td>
</tr>
<tr>
<td>MMRC</td>
<td>0.5 (0.2, 0.8)</td>
<td>0.002</td>
</tr>
<tr>
<td>SGRQ</td>
<td>6.4 (0.3, 12.5)</td>
<td>0.039</td>
</tr>
<tr>
<td><strong>Exacerbations (total freq.) b</strong></td>
<td>IRR</td>
<td>P</td>
</tr>
<tr>
<td>Mod/Severe</td>
<td>2.2 (1.1, 4.5)</td>
<td>0.031</td>
</tr>
</tbody>
</table>

a Generalized linear mixed model with gaussian probability distribution and identity link and random intercept for participant was used in regressing the repeated measures of the continuous respiratory outcome on the dichotomous food insecurity measure at participant-level, adjusted by the covariates as specified below for models 1 & 2. The table shows the point estimate and the 95% confidence interval of the predicted mean difference in the outcome level between the participants who were ever food insecure during the study and those who were food secure at all times, adjusted by the covariates.

b Cross-sectional negative binomial regression of the total frequency of exacerbation (for the entire study period) was run on the dichotomous food insecurity variable measure at participant-level, with total follow-up days included as an offset, and adjusted by covariates as specified below. The table shows the point estimate and the 95% confidence interval of the predicted incidence rate ratio (IRR) of the exacerbation between the participants who were ever food insecure during the study and those who were food secure at all times, adjusted by the covariates.

The models were adjusted by the baseline covariates as follows:
- Model 1 (Parsimonious): demographics (age, gender, race) & individual risk factors (smoking pack-years, BMI, comorbidity, controller medication use, FEV1 % predicted)
- Model 2 (Primary): Model 1 + individual SES (education, household income) + neighborhood SES (poverty rate, limited food access)
### Table 3. Association between Subdomains of Food Insecurity and COPD Morbidity

<table>
<thead>
<tr>
<th></th>
<th>Anxiety &amp; Uncertainty about the Household Food Supply</th>
<th>Insufficient Food Quality</th>
<th>Insufficient Food Intake &amp; Its Physical Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Difference</td>
<td>Mean Difference</td>
<td>Mean Difference</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td><strong>Respiratory symptoms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAT</td>
<td>6.1 (3.1, 9.1)</td>
<td>3.4 (0.6, 6.1)</td>
<td>4.0 (0.9, 7.1)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.001</td>
<td>0.016</td>
<td>0.010</td>
</tr>
<tr>
<td>mMRC</td>
<td>0.3 (-0.1, 0.6)</td>
<td>0.5 (0.2, 0.7)</td>
<td>0.5 (0.1, 0.8)</td>
</tr>
<tr>
<td></td>
<td>0.151</td>
<td>0.002</td>
<td>0.010</td>
</tr>
<tr>
<td>SGRQ</td>
<td>8.9 (2.3, 15.6)</td>
<td>7.6 (1.5, 13.7)</td>
<td>7.2 (-0.3, 14.6)</td>
</tr>
<tr>
<td></td>
<td>0.009</td>
<td>0.014</td>
<td>0.060</td>
</tr>
<tr>
<td><strong>Exacerbations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(total freq.) b</td>
<td>IRR</td>
<td>IRR</td>
<td>IRR</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Mod/Severe</td>
<td>0.9 (0.3, 2.3)</td>
<td>2.3 (1.1, 4.7)</td>
<td>0.6 (0.2, 1.8)</td>
</tr>
<tr>
<td></td>
<td>0.802</td>
<td>0.020</td>
<td>0.356</td>
</tr>
</tbody>
</table>

* Generalized linear mixed model with gaussian probability distribution and identity link and random intercept for participant was used in regressing the repeated measures of the continuous respiratory outcome on the dichotomous food insecurity subdomain measure at participant-level, adjusted by the covariates in the primary model. The table shows the point estimate and the 95% confidence interval of the predicted mean difference in the outcome level between the participants who were ever food insecure during the study and those who were food secure at all times within the subdomain, adjusted by the covariates.

b Cross-sectional negative binomial regression of the total frequency of exacerbations for the study period was run on the dichotomous food insecurity subdomain measure at participant-level, with total follow-up days included as an offset, and adjusted by covariates. The table shows the point estimate and the 95% confidence interval of the predicted incidence rate ratio (IRR) of the exacerbation between the participants who were ever food insecure during the study and those who were food secure at all times within the subdomain, adjusted by the covariates.

Models were adjusted by baseline covariates specified in the primary analysis (Model 2): demographics (age, gender, race) & individual risk factors (smoking pack-years, BMI, comorbidity, controller medication use, FEV1 % predicted), individual SES (education, household income), and neighborhood SES (poverty rate, limited food access).
Table 4. Association between Food Insecurity and Psychological Wellbeing

<table>
<thead>
<tr>
<th>Psychological Well-Being Measures</th>
<th>Model 1 (Parsimonious)</th>
<th>Model 2 (Primary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference</td>
<td>P</td>
<td>Mean Difference</td>
</tr>
<tr>
<td><strong>Depressive Symptom Score</strong></td>
<td>1.2 (-0.3, 2.7)</td>
<td>0.124</td>
</tr>
<tr>
<td><strong>Anxiety Symptom Score</strong></td>
<td>1.4 (0.0, 2.8)</td>
<td>0.046</td>
</tr>
<tr>
<td><strong>Perceived Stress Scale</strong></td>
<td>3.7 (0.6, 6.8)</td>
<td>0.020</td>
</tr>
</tbody>
</table>

*a Generalized linear mixed model with gaussian probability distribution and identity link and random intercept for participant was used in regressing the repeated measures of the continuous psychological wellbeing measures on the dichotomous food insecurity measure at participant-level, adjusted by the covariates as specified below for models 1 & 2. The table shows the point estimate and the 95% confidence interval of the predicted mean difference in the psychological wellbeing level between the participants who were ever food insecure during the study and those who were food secure at all times, adjusted by the covariates.

The models were adjusted by the baseline covariates as follows:

- Model 1 (Parsimonious): demographics (age, gender, race) & individual risk factors (smoking pack-years, BMI, comorbidity, controller medication use, FEV1 % predicted)
Figure 1
Online Supplement

Inclusion criteria
Initial encatchment area was restricted to Baltimore city and defined by zip codes with median yearly income below US $60,000 from East Baltimore. This was expanded to include Baltimore city and the greater Baltimore–Washington metropolitan area in census blocks where more than 10% of households had income below the federal poverty level. The poverty rate definition was derived from the Department of Treasury New Markets Tax Credit Program evaluation Final Report from 2013. (http://www.urban.org/sites/default/files/alfresco/publication-pdfs/412958-New-Markets-Tax-Credit-NMTC-Program-Evaluation.PDF), and referenced by the USDA Economic Research Service.*Data on poverty by census block groups (n=647) for Baltimore City (source: 2013 ACS survey (5 year)).

Participant compensation
Acknowledging the burden on participants of multiple and lengthy study visits, participants were compensated up to a total of $570 for completion of all study activities and referral of another eligible participant.

Exclusion criteria
Individuals were excluded from the study were those who were taking chronic systemic corticosteroids (i.e., >10 mg daily prednisone during three months in the prior year), had another chronic lung disease excepting a diagnosis of asthma, were living in a facility or planning to move within the study period (given that one of the primary aims of CURE COPD was to measure indoor air pollutants longitudinally), or were underweight (body mass index [BMI] <18.5)

Treatment of food insecurity variable
Per guidelines,20 both a categorical and a continuous indicator of food insecurity were separately constructed. For the categorical indicator, participant’s household was classified as either 1) food secure, 2) mildly insecure, 3) moderately insecure, or 4) severely insecure. For the continuous indicator, the scale ranged from 0 to 27, with the higher score indicating greater severity of food insecurity. Given the skewed distribution of HFIAS as a continuous indicator—due to a large majority of participants reporting as food secure at each visit (~>85%)—the primary analysis used HFIAS as a categorical indicator with just two categories: food secure vs food insecure (of any severity). Additionally, given the temporal rigidity of those who are food secure to remain secure from one visit to next (>90%), the primary analysis operationalized food insecurity as either food secure at all times or else insecure (i.e., if falling into food insecurity at least once during the 6-month study).