# Association between socioeconomic status and chronic obstructive pulmonary disease in Jiangsu province, China: a population-based study

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**Abstract**

**Background:** Chronic obstructive pulmonary disease (COPD) is a common public health problem worldwide. Recent studies have reported that socioeconomic status (SES) is related to the incidence of COPD. This study aimed to investigate the association between SES and COPD among adults in Jiangsu province, China, and to determine the possible direct and indirect effects of SES on the morbidity of COPD.

**Methods:** A cross-sectional study was conducted among adults aged 40 years and above between May and December of 2015 in Jiangsu province, China. Participants were selected using a multistage sampling approach. COPD, the outcome variable, was diagnosed by physicians based on spirometry, respiratory symptoms, and risk factors. Education, occupation, and monthly family average income (FAI) were used to separately indicate SES as the explanatory variable. Mixed-effects logistic regression models were introduced to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for examining the SES-COPD relationship. A pathway analysis was conducted to further explore the pulmonary function impairment of patients with different SES.

**Results:** The mean age of the 2421 participants was $56.63 \pm 9.62$ years. The prevalence of COPD was 11.8% (95% CI: 10.5%–13.1%) among the overall sample population. After adjustment for age, gender, residence, outdoor and indoor air pollution, body weight status, cigarette smoking, and potential study area-level clustering effects, educational attainment was negatively associated with COPD prevalence in men; white collars were at lower risk (OR: 0.60, 95% CI: 0.43–0.83) of experiencing COPD than blue collars; compared with those within the lower FAI subgroup, participants in the upper (OR: 0.68, 95% CI: 0.49–0.97) tertiles were less likely to experience COPD. Such negative associations between all these three SES indicators and COPD were significant among men only. Education, FAI, and occupation had direct or indirect effects on pulmonary function including post-bronchodilator forced expiratory volume in 1 s/forced vital capacity ($FEV_1/FVC$), $FEV_1$, FVC, and $FEV_1$ percentage of predicted. Education, FAI, and occupation had indirect effects on pulmonary function indices of all participants mainly through smoking status, indoor air pollution, and outdoor air pollution. We also found that occupation could affect post-bronchodilator $FEV_1/FVC$ through body mass index.

**Conclusions:** Education, occupation, and FAI had an adverse relationship with COPD prevalence in Jiangsu province, China. SES has both direct and indirect associations with pulmonary function impairment. SES is of great significance for COPD morbidity. It is important that population-based COPD prevention strategies should be tailored for people with different SES.

**Keywords:** Socioeconomic status; Family average income; Smoking; Air pollution; Body mass index; Chronic obstructive pulmonary disease

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## Introduction

Chronic obstructive pulmonary disease (COPD) is a common public health problem worldwide. It is currently one of the top three causes of death in the world.[1] Moreover, the burden caused by COPD is particularly heavy in developing countries, including China, which is the most populated country in the world.[2] The recently estimated spirometry-based COPD prevalence is as high as 13.7% among the general population aged 40 years and above in China.[3] COPD has always been considered to be a preventable and treatable disease with some significant extrapulmonary effects that may contribute to the impairment of pulmonary function and increase its prevalence.[4] Therefore, it is necessary to have a good understanding of the risk factors associated with COPD prevalence and lung function decline while designing appropriate COPD preventive measures.

Previous studies have confirmed that cigarette smoking, indoor air pollution, and outdoor air pollution are the leading risk factors for COPD.[3,5] Other studies have mentioned that low socioeconomic status (SES) is also related to the incidence of COPD.[3,6-9] SES is a broad concept that is often measured by occupation, family economic status, and education level in scientific research.[10-13] Recently, family average income (FAI) has been considered to be the most appropriate representative indicator of family economic status. This is because it is documented to be more sensitive and realistic in reflecting the material wealth and social position.[11,14-17]

For COPD prevention, it is helpful to identify subpopulations at different SES levels in SES-specific effective intervention campaigns. In addition, most studies only focused on the effect of a single risk factor, without analyzing them to explore the overall impact on COPD prevalence or pulmonary function decline. To bridge this gap, we used education, occupation, and FAI to separately predict SES. Furthermore, we conducted a population-based study to investigate the relationship between SES and COPD prevalence among adults in the Jiangsu province of China. Previous studies suggested that education, occupation, and income had an impact on smoking, exposure to environmental pollution, and body mass index (BMI). Smoking, environmental pollution, and low BMI are classic risk factors for COPD prevalence.[3,6,14,15] Therefore, this study conducted a pathway analysis to further explore the pulmonary function impairment of patients with different SES and related factors among all of the participants.

## Methods

### *Ethical approval*

This study was approved by the Ethics Review Committee of the National Center for Chronic and Non-communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention (No. 201410). Each participant provided the written informed consent before the survey. Participants' identities were excluded from the analysis.

### *Participants*

This cross-sectional study, with the initial aim of investigating COPD prevalence among adults aged 40 years and above, was conducted between May and December of 2015 in Jiangsu province, China. Jiangsu province, in the eastern region of China, has 13 administrative municipalities/cities under the current administrative system (five strata: central, provincial, municipal/city, district/county, and street/township) in China. A disease surveillance point (DSP) system was established to periodically collect data on specific disease prevalence and risk behaviors as well as mortality among representative sample populations in China. In total, 605 district/county-based DSPs have been established, with one from each selected municipality or city in China. In Jiangsu province, six DSPs (three urban districts and three rural counties) within six different cities were randomly selected accounting for a representative sample population.

Those household residents who were aged 40 years and above had been registered for 6 months and above were eligible to participate in the present study. However, residents with cognitive/literal/mental disorders, diagnosed with cancers, or paraplegia were not recruited. Pregnant women were also excluded. A multistage sampling method was employed to randomly select participants. The sample size was estimated based on the following aspects: (1) study design and sampling approach; (2) the available COPD prevalence (8.2% among adults aged over 40 years in China)[5,18,19]; and (3) an expected 90% response rate. Therefore, the sufficient sample size was estimated to be approximately 2600. Next, we randomly selected participants using a multistage sampling approach: (1) two/three streets/towns were randomly determined from each DSP urban district/rural county, respectively; (2) two neighborhoods were chosen from each street and two villages from each town; and (3) one eligible participant was recruited from each of the 100 selected households within each determined neighborhood/village using a Kish grid sampling approach.[5]

### *Data collection*

In this study, in addition to the function test, each participant took part in a face-to-face questionnaire interview and the anthropometric examination. Information integrated into the questionnaire was on each participant's socio-demographic characteristics (including education, occupation, and income), personal medical history, parental history of respiratory disease, respiratory symptoms, and influencing factors of respiratory disease (eg, cigarette smoking).

### *Spirometry*

Each participant underwent a pulmonary function test with calibrated spirometers (MasterScreen Pneumo, Jaeger, Germany) based on the American Thoracic Society's recommendations by trained workers from local CDC or community health service centers.[20,21] Participants who were allergic to salbutamol or had a resting heart rate of over 100 beats per min, were excluded from the post-bronchodilator examination. After the administration of 400 μg of salbutamol (Ventolin; GlaxoSmithKline, Middlesex, UK) for 15 min, each eligible subject underwent a post-bronchodilator spirometry. Pre-bronchodilator and post-bronchodilator forced vital capacity (FVC) and forced expiratory volume in 1 s ($FEV_1$) were assessed separately.

## Study variables

### Outcome variable

In the prevalence study section, the outcome event was spirometry-defined COPD, which was defined according to the 2017 Global Initiative for Chronic Obstructive Lung Disease guideline.[20] A participant was defined as a patient with COPD, if he/she had a post-bronchodilator $FEV_1$/FVC of less than 70%, with respiratory symptoms and exposure to risk factors. Respiratory symptoms included chronic cough, expectoration, and shortness of breath. Risk factors for COPD included exposure to cigarette smoking, exposure to particulate matter (PM) with a diameter less than 2.5 μm, underweight, childhood chronic cough or frequent cough, and parental history of respiratory diseases.[3] In pathway analysis, the path variables were pulmonary function test indexes, including post-bronchodilator $FEV_1$/FVC, $FEV_1$, FVC, and $FEV_1$ percentage of predicted ($FEV_1$% pred).

### Explanatory variables

The explanatory variables were SES, which was indicated by education, occupation, and FAI, respectively. Educational level was grouped into three categories based on years of schooling completed: 9 years (compulsory education level), 10 to 12 years (senior high school), or over 13 years (college or greater). The occupation was categorized into two groups: blue collar (farmers, factory workers, forestry workers, fishers, salespersons, houseworkers, and vehicle drivers), or white collar (office workers, teachers, doctors, academic researchers, and government officials). FAI refers to the monthly average income within a household, which is computed as the total monthly household income divided by the total number of family members. For the analysis, the FAI was classified into three subgroups: lower, middle, or upper tertile.

### Other covariates

Some potential influencing factors were considered as covariates in the analysis, including age, gender, residence, cigarette smoking, outdoor and indoor air pollution, parental history of respiratory diseases, and body weight status.[3,5] They were treated as categorical variables in the multivariable analysis. Participants were classified into four age groups (40–49, 50–59, 60–69, and over 70 years old), two gender categories (men *vs*. women), and two residential locations (urban *vs*. rural residence).

Current smokers were defined as those who continuously smoked at least one cigarette every day for at least 1 year or totally smoked over 18 packs within a year. Former smokers referred to people who met the criteria of current smokers previously but had not smoked for >1 year. All the subjects who did not meet the current or former smokers' criteria were classified as non-smokers.[22] Participants were categorized into: smokers (current/former smokers), or non-smokers in the analysis.

Outdoor air pollution was indicated by PM2.5 concentration. We collected time point PM2.5 concentrations every day for each study site from the provincial environment monitoring system.[23] We then calculated the arithmetic mean value of daily PM2.5 concentrations for each study site. Participants were categorized as follows: exposure to either ≥75 or <75 $\mu g/m^3$ according to Chinese ambient air quality standards.[3,24]

Indoor air pollution was predicted based on the type of fuel used for cooking or heating within households. Biomass fuels included coal, wood, grass, and crop residues, while non-biomass fuels included natural gas, electricity, and solar energy.[25] Thus, the subjects were grouped into biomass use or non-biomass use.

Parental history of respiratory disease was defined as positive or negative. Positive history was defined as the father/mother having been diagnosed with any of the following respiratory diseases: asthma, chronic bronchitis, emphysema, COPD, pulmonary heart disease, or bronchiectasis; while negative history included that neither of the parents had been diagnosed with any of the diseases mentioned above.

Body weight status was defined as BMI using the cutoffs recommended for Chinese adults.[26] Participants were categorized into three subgroups: BMI <24 $kg/m^2$, BMI 24 to 27 $kg/m^2$, or BMI ≥28 $kg/m^2$. We objectively assessed subjects' body weight to the nearest 0.1 kg and body height to 0.1 cm, and then computed BMI as body weight (kg) divided by the square of body height ($m^2$).

## Statistical analysis

In the prevalence study section, the relationships between sub-populations at different SES levels and the prevalence of COPD were analyzed. First, differences in COPD prevalence according to different sociodemographic characteristics and influencing factors were examined using the Chi-square test for categorical variables or *t*-test for continuous variables. Then, mixed-effects logistic regression models were introduced to compute odds ratios (ORs) and 95% confidence intervals (95% CIs) for investigating associations between SES indicators and COPD, with study sites treated as random effects. Two models were constructed: one was a univariable model with each SES indicator as the main effect, and a multivariable model with adjustment for potential risk factors of COPD (age, gender, residence, outdoor and indoor air pollution, body weight status, and cigarette smoking). Receiver operating characteristic (ROC) curve analyses were used to identify the utility of SES indices for the prediction of COPD diagnosis. Statistical significance was set at $P < 0.05$.

In the pathway analysis section, the relationship between explanatory variables, covariates, and pulmonary function test indexes of the participants was quantitatively analyzed using multiple linear regression analysis. First, hypotheses pathways were put forward based on previous studies. Second, taking each endogenous variable as the dependent variable and the variable pointed by the arrow as the independent variable, a linear regression equation was established to obtain the regression coefficient. Then, we obtain the direct and indirect effects of the independent variables on the pulmonary function test indexes each through the path coefficients and the product of the path coefficients. Finally, we obtained the total effect of SES status on lung function indices by integration. Repeated calls to the linear procedure were used for path analyses. Results were considered statistically significant at $P < 0.05$. All of the above analyses were performed using IBM SPSS Statistics for Windows, version 21.0 (IBM Corp, Armonk, NY, USA).

## Results

The six included DSPs were Yuhuatai District in Nanjing, Yangzhong County in Zhenjiang, Jiangyin County in Wuxi, Haizhou District in Lianyungang, Huai'an District in Huai'an, and Liyang County in Changzhou. Finally, there were 13 administrative streets/towns, 14 neighborhoods, 12 villages, and 2600 households included in this study. We recruited one eligible participant from each of the selected households. Of the 2600 eligible participants, 2421 completed the study (response rate 93.1%). There were no significant differences in sociodemographic characteristics between those who completed and did not complete the study. Table 1 presents the participants' sociodemographic and anthropometric characteristics. Among the respondents, the mean age (standard deviation) was $56.63 \pm 9.62$ years for overall participants, $57.47 \pm 9.69$ years for men, and $55.81 \pm 9.49$ years for women. In addition, 49.6% (1201/2421) were urban participants, with 49.1% (1188/2421) of men; 79.6% (1928/2421) had less than 9-schooling years; 69.1% (1673/2421) had blue collar jobs; and 17.3% (420/2421) were obese individuals.

**Table 1: Selected socio-demographic and anthropometric characteristics of participants in this study ($n = 2421$).**

| Items | n | Percentage (%) |
|---|---|---|
| Age (years) | | |
| 40–49 | 646 | 26.7 |
| 50–59 | 821 | 33.9 |
| 60–69 | 710 | 29.3 |
| ≥70 | 244 | 10.1 |
| Residence | | |
| Urban | 1201 | 49.6 |
| Rural | 1220 | 50.4 |
| Gender | | |
| Men | 1188 | 49.1 |
| Women | 1233 | 50.9 |
| Educational attainment (years) | | |
| ≤9 | 1928 | 79.6 |
| 10–12 | 405 | 16.7 |
| ≥13 | 88 | 3.6 |
| Occupation* | | |
| Blue collar | 1673 | 69.1 |
| White collar | 748 | 30.9 |
| FAI (tertile) | | |
| Lower | 823 | 34.0 |
| Middle | 856 | 35.4 |
| Upper | 742 | 30.6 |
| BMI ($kg/m^2$)† | | |
| <24 | 935 | 38.6 |
| 24–27 | 1066 | 44.0 |
| ≥28 | 420 | 17.3 |

* Blue collars included farmers, factory workers, forestry workers, fishers, salespersons, houseworkers, and vehicle drivers; white collars included office workers, teachers, doctors, academic researchers, and government officials. † Body weight status was assessed based on BMI cutoffs specifically recommended for Chinese adults. BMI: Body mass index; FAI: Family average income.

Table 2 shows COPD prevalence among participants with different characteristics in this study. The overall prevalence of COPD was 11.8% (95% CI: 10.5%–13.1%). The prevalence of COPD steadily increased with an increase in participants' age. COPD prevalence was significantly higher in men (17.8%) than women (6.0%). However, there was no significant difference in COPD prevalence between urban (12.6%) and rural (11.0%) residents. Undoubtedly, the prevalence was higher among smokers (20.0%) compared with non-smokers (6.0%). Also, the prevalence of COPD was higher for residents living in areas with PM2.5 concentration $\geq 75$ $\mu g/m^3$ (13.8%) than in those with PM2.5 concentration $< 75$ $\mu g/m^3$ (10.7%).

Table 3 displays associations of SES indicators with COPD among participants. After adjustment for age, gender, residence, outdoor and indoor air pollution, body weight status, cigarette smoking, and potential clustering effects by study areas, educational level was negatively associated with the prevalence of COPD in men. White collars were at lower risk (OR: 0.60, 95% CI: 0.43–0.83) of experiencing COPD than blue collars. Compared with those within the lower FAI tertile subgroup, participants within the upper (OR: 0.68, 95%CI: 0.49–0.97) tertiles were less likely to experience COPD. Considering only 74 COPD cases in women, we performed a stratified analysis by gender, and found that such negative associations between all these three SES indicators and COPD prevalence were significant among men only. Moreover, it seemed that FAI was a more sensitive index of SES in this study. There was a higher area under the ROC curve (AUC) of FAI (AUC = 0.8025) compared with education (AUC = 0.7688) and occupation (AUC = 0.7223) in ROC curve analyses for the prediction of COPD diagnosis.

Table 4 and Supplementary Figure 1, http://links.lww.com/CM9/A690 display the decomposition effect of education, occupation, and FAI on pulmonary function test indexes through BMI, cigarette smoking, and indoor and outdoor air pollution. As expected, we found statistically significant direct correlations between all of the SES variables and $FEV_1/FVC$, $FEV_1$, and FVC (all $P < 0.01$). The weakest relationship existed between occupation and $FEV_1/FVC$ with a $\beta$ coefficient of $-0.042$, and the strongest relationship existed between education and $FEV_1$ with a $\beta$ coefficient of 0.284. As for $FEV_1$% pred, only educational level had a significant direct relationship with it ($\beta = -0.076$). Education had an indirect effect on FVC and $FEV_1$% pred by

**Table 2: Prevalence of COPD among participants by socio-demographic attributes and risk factors in this study.**

| Items | COPD prevalence ($n = 2421$) | | | |
|---|---|---|---|---|
| | $n$ | % (95% CI) | $\chi^2$ values | $P$ values |
| Overall | 285 | 11.8 (10.5, 13.1) | | |
| Age (years) | | | 139.81 | <0.001 |
| 40–49 | 20 | 3.1 (1.8, 4.4) | | |
| 50–59 | 71 | 8.6 (6.7, 10.6) | | |
| 60–69 | 126 | 17.7 (14.9, 20.6) | | |
| ≥70 | 68 | 27.9 (22.2, 33.5) | | |
| Residence | | | 1.47 | 0.225 |
| Urban | 151 | 12.6 (10.7, 14.4) | | |
| Rural | 134 | 11.0 (9.2, 12.7) | | |
| Gender | | | 80.56 | <0.001 |
| Men | 211 | 17.8 (15.6, 19.9) | | |
| Women | 74 | 6.0 (4.7, 7.3) | | |
| Educational attainment (years) | | | 8.59 | 0.014 |
| ≤9 | 245 | 12.7 (11.2, 14.2) | | |
| 10–12 | 35 | 8.6 (5.9, 11.4) | | |
| ≥13 | 5 | 5.7 (0.8, 10.5) | | |
| Occupation* | | | 1.53 | 0.217 |
| Blue collar | 206 | 12.3 (10.7, 13.9) | | |
| White collar | 79 | 10.6 (8.4, 12.8) | | |
| FAI (tertile) | | | 26.82 | <0.001 |
| Lower | 135 | 16.4 (13.9, 18.9) | | |
| Middle | 87 | 10.2 (8.1, 12.2) | | |
| Upper | 63 | 8.5 (6.5, 10.5) | | |
| BMI (kg/m$^2$)† | | | 7.74 | 0.021 |
| <24 | 130 | 11.3 (11.7, 16.1) | | |
| 24–27 | 117 | 11.0 (9.1, 12.9) | | |
| ≥28 | 38 | 9.0 (6.3, 11.8) | | |
| Smoking status‡ | | | 111.05 | <0.001 |
| Smokers | 200 | 20.0 (17.5, 22.4) | | |
| Non-smokers | 85 | 6.0 (4.8, 7.2) | | |
| Outdoor air pollution (PM2.5) | | | 5.07 | 0.023 |
| <75 μg/m$^3$ | 169 | 10.7 (9.2, 12.2) | | |
| ≥75 μg/m$^3$ | 116 | 13.8 (11.5, 16.1) | | |

* Blue collars included farmers, factory workers, forestry workers, fishers, salespersons, houseworkers, and vehicle drivers; white collars included office workers, teachers, doctors, academic researchers, and government officials. † Body weight status was assessed based on BMI cutoffs specifically recommended for Chinese adults. ‡ Smokers referred to either current (continuously smoked at least one cigarette every day for at least 1 year or totally smoked over 18 packs in a year) or former (met the criteria of current smokers previously but had not smoked for >1 year) smokers, while non-smokers were those not meeting the current/former smokers' criteria. BMI: Body mass index; CI: Confidence interval; COPD: Chronic obstructive pulmonary disease; FAI: Family average income; PM2.5: Particulate matter (PM) with a diameter less than 2.5 μm.

influencing outdoor air pollution, and the indirect effect coefficients were 0.011 and −0.018, respectively. Occupation affected $FEV_1$/FVC by influencing BMI, cigarette smoking and indoor air pollution, and the $\beta$ coefficient of the total indirect effect was −0.009. Occupation can affect $FEV_1$ through cigarette smoking ($\beta = 0.033$), and affect FVC through cigarette smoking and indoor air pollution ($\beta = 0.038$). FAI had indirect effects on $FEV_1$/FVC ($\beta = 0.025$) through cigarette smoking and indoor air pollution; FAI indirectly affected FVC ($\beta = -0.037$) through cigarette smoking and outdoor air pollution.

## Discussion

In the present study, we sought to investigate the association between SES, including education, occupation, and FAI, and COPD prevalence among adults aged 40 years and above in Jiangsu province of China. It was observed that white collars, or participants within the upper FAI tertile, were less likely to experience COPD. However, such negative associations remained only for men but not for women in the gender-stratified analysis. At present, the most authoritative epidemiological studies of COPD prevalence in China are all based on spirometry, because lung function indices are the most important standards for the diagnosis of COPD.[3,5] Therefore, we further focused on the influence of SES on the lung function indices to explore the reasons for the COPD prevalence disparity between men and women caused by SES.

Our findings were in line with those of previous studies[6-9] in that either of occupation or FAI was inversely associated with COPD. In our study, the main risk factors for COPD such as cigarette smoking and air pollution were controlled. Notably, the SES–COPD relationship was

Table 3: Associations between SES and COPD among participants in this study.

| Items | Overall (n = 2421) COPD prevalence, n (%) | Overall OR (95% CI) Model 1* | Overall OR (95% CI) Model 2† | Men (n = 1188) COPD prevalence, n (%) | Men OR (95% CI) Model 1* | Men OR (95% CI) Model 2† | Women (n = 1233) COPD prevalence, n (%) | Women OR (95% CI) Model 1* | Women OR (95% CI) Model 2† | Gender interaction OR (95% CI) Model 1* | Gender interaction OR (95% CI) Model 2† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Educational attainment (years)‡ | | | | | | | | | | | |
| ≤9 | 245/1928 (12.7) | 1 | 1 | 176/893 (19.7) | 1 | 1 | 69/1033 (6.7) | 1 | 1 | 1 | 1 |
| 10–12 | 35/405 (8.6) | 0.65 (0.45, 0.94) | 0.72 (0.48, 1.07) | 32/239 (13.4) | 0.63 (0.42, 0.95) | 0.81 (0.53, 1.24) | 3/168 (1.8) | 0.26 (0.08, 0.82) | 0.37 (0.11, 1.21) | 0.61 (0.78, 0.79) | 0.78 (0.59, 1.03) |
| ≥13 | 5/88 (5.7) | 0.41 (0.17, 1.03) | 0.41 (0.16, 1.07) | 3/56 (5.4) | 0.23 (0.07, 0.75) | 0.27 (0.08, 0.90) | 2/32 (6.3) | 0.93 (0.22, 3.98) | 1.94 (0.43, 8.79) | 0.58 (0.34, 0.99) | 0.73 (0.39, 1.37) |
| Occupation§ | | | | | | | | | | | |
| Blue collar | 206/1673 (12.3) | 1 | 1 | 149/777 (19.2) | 1 | 1 | 57/893 (6.4) | 1 | 1 | 1 | 1 |
| White collar | 79/748 (10.6) | 0.84 (0.64, 1.11) | 0.60 (0.43, 0.83) | 62/411 (15.1) | 0.75 (0.54, 1.04) | 0.62 (0.43, 0.90) | 17/340 (5.0) | 0.78 (0.45, 1.36) | 0.60 (0.31, 1.16) | 0.57 (0.49, 0.66) | 0.73 (0.62, 0.87) |
| FAI (tertiles) | | | | | | | | | | | |
| Lower | 135/823 (16.4) | 1 | 1 | 101/385 (26.2) | 1 | 1 | 34/437 (7.8) | 1 | 1 | 1 | 1 |
| Middle | 87/856 (10.2) | 0.58 (0.43, 0.77) | 0.78 (0.57, 1.07) | 60/422 (14.2) | 0.47 (0.33, 0.67) | 0.62 (0.42, 0.89) | 27/435 (6.2) | 0.79 (0.47, 1.33) | 1.39 (0.78, 2.47) | 0.61 (0.51, 0.74) | 0.91 (0.73, 1.13) |
| Upper | 63/742 (8.5) | 0.47 (0.34, 0.65) | 0.68 (0.49, 0.97) | 50/381 (13.1) | 0.43 (0.29, 0.62) | 0.63 (0.42, 0.93) | 13/361 (3.6) | 0.44 (0.23, 0.86) | 0.82 (0.41, 1.64) | 0.51 (0.41, 0.63) | 0.76 (0.59, 0.98) |

*Model 1 was a univariable analysis with SES indicators as main effects and study sites as random effects. †Model 2 was a multivariable analysis after adjustment for age, gender, residence, outdoor and indoor air pollution, body weight status and cigarette smoking, in addition to Model 1. ‡Educational attainment referred to schooling years completed. §Blue collars included farmers, factory workers, forestry workers, fishers, salespersons, houseworkers, and vehicle drivers; white collars included office workers, teachers, doctors, academic researchers, and government officials. CI: Confidence interval; COPD: Chronic obstructive pulmonary disease; FAI: Family average income; OR: Odds ratio; SES: Socioeconomic status.

independent of the two main risk factors, which is consistent with previous reports overseas.[8,27,28] We also conducted the path analyses and identified several factors that lead to different COPD prevalences at various levels of SES. To our knowledge, this is the first study that attempts to understand the related factors and pathways associated with SES, pulmonary function impairment, and COPD prevalence in China. We identified four variables, including BMI, cigarette smoking, and indoor and outdoor air pollution, in the path analysis of the SES-related factors for pulmonary function impairment in COPD. The results suggested that education, FAI, and occupation not only had direct effects on pulmonary function test indexes (post-bronchodilator $FEV_1$/FVC, $FEV_1$, FVC, $FEV_1$% pred), but also had indirect effects on them through smoking status, indoor air pollution, and outdoor air pollution.

The underlying mechanism may include the following aspects: First, people with low SES might engage in more unhealthy behaviors and poor nutrition and consequently become at high risk for COPD.[3,29] Second, residents with low SES might have disadvantages in accessing health care services which possibly led to worse health outcomes.[30] Third, participants with low SES might not have satisfactory self-protection against risk factors and thus are subsequently exposed to them, for example, outdoor/indoor air pollution.[7,31] Fourth, the impact of different SES on COPD prevalence and lung function injury between men and women may be due to indirect factors (smoking, indoor and outdoor air pollution). In China, cigarette smoking is still cardinally a male behavior, and of all smokers, male accounted for 74%, while females for only 8%.[32] For females in China, with the economic growth over past decades, clean energy and kitchen ventilators might become easily affordable and widely used for cooking and heating in households. Indoor air pollution caused by domestic fuels used, kitchen ventilation, and heating in winter which is a great threat to women is now diminished.[33,34] For males in China, jobs with higher outdoor air pollution are still mainly undertaken by them. Exposure to outdoor air pollutants is significantly correlated with increasing emphysema and worsening lung function.[35]

The SES disparity in COPD is a public health concern. It was shown to have a greater impact on medical care accessible to the COPD patients.[36] It is important to well understand the direct and indirect relationship between SES and COPD for population-based COPD prevention worldwide, particularly in China, where rapid economic growth has been causing SES inequality over past decades.[37,38] Different indices used to predict SES might display different scenarios of the SES–COPD relationship. The different scenarios of SES play a role through different classic factors. Thus, it is necessary to explore SES–COPD associations with different indices. This would help develop community-based COPD intervention programs tailored for SES index-sensitive subgroups of the population. Moreover, SES disparity in COPD might change with social and economic development. Therefore, it is necessary to continuously monitor and investigate SES–COPD relationship in the future.

This study had several strengths. First, COPD was diagnosed based on spirometry, respiratory symptoms,

**Table 4: Path analysis for the associations between education, occupation, FAI, and pulmonary function test indexes.**

| Independent variables | Dependent variables | $\beta$ values of direct effects | $\beta$ values of indirect effects | $\beta$ values of total effects |
|---|---|---|---|---|
| Education | BMI | 0.001 | – | 0.001 |
| | Cigarette smoking | 0.029 | – | 0.029 |
| | Indoor air pollution | −0.139 | – | −0.139 |
| | Outdoor air pollution | −0.123 | – | −0.123 |
| | $FEV_1$/FVC | 0.113 | −0.001 | 0.112 |
| | $FEV_1$ | 0.284 | 0.010 | 0.294 |
| | FVC | 0.249 | 0.011 | 0.260 |
| | $FEV_1$% pred | −0.076 | −0.018 | −0.094 |
| Occupation | BMI | 0.045 | – | 0.045 |
| | Cigarette smoking | 0.069 | – | 0.069 |
| | Indoor air pollution | −0.183 | – | −0.183 |
| | Outdoor air pollution | 0.122 | – | 0.122 |
| | $FEV_1$/FVC | −0.042 | −0.009 | −0.051 |
| | $FEV_1$ | −0.102 | 0.033 | −0.069 |
| | FVC | −0.092 | 0.038 | −0.054 |
| | $FEV_1$% pred | 0.029 | −0.001 | 0.028 |
| Family average income | BMI | 0.017 | – | 0.017 |
| | Cigarette smoking | −0.060 | – | −0.060 |
| | Indoor air pollution | −0.117 | – | −0.117 |
| | Outdoor air pollution | −0.251 | – | −0.251 |
| | $FEV_1$/FVC | 0.043 | 0.025 | 0.068 |
| | $FEV_1$ | 0.066 | −0.025 | 0.041 |
| | FVC | 0.049 | −0.037 | 0.012 |
| | $FEV_1$% pred | −0.028 | −0.013 | −0.041 |

Data were shown as $\beta$ values with statistical significance. All the $\beta$ values in this table were adjusted for age, gender, residence, and parental history of respiratory diseases. BMI: Body mass index; FAI: Family average income; $FEV_1$: Forced expiratory volume in 1 s; $FEV_1$% pred: $FEV_1$ percentage of predicted; FVC: Forced vital capacity; –: Not applicable.

and risk factors. Furthermore, the three classic indices of SES, that is, education, occupation, and FAI were used separately to examine the SES–COPD relationship, showing that FAI was more sensitive as an SES indicator. Remarkably, the main risk factors of COPD, smoking and air pollution, were manipulated in the current study. In addition, potential clustering effects in the study area were considered in the analysis.

Of note, there were some limitations to this study. First, it was a cross-sectional survey. Thus, no causal association could be addressed. Second, the sample size was estimated to investigate the SES–COPD relationship among overall adults without consideration of stratified analysis, which led to few COPD cases identified in women. Third, information on SES indicators was self-reported, which might have caused a potential recall bias. For example, personal income may be under-reported. Although data were initially collected in late 2015, data were actually entered and arranged in 2017, and then were made available in 2018. The experimental data at hand were the latest population-based information regarding COPD in both Jiangsu province and China. As SES may change for people with social development, dynamically investigating the relationship between SES and COPD is of significant importance for identifying SES-vulnerable people for tailored population-based COPD prevention campaigns. Fourth, the pathway construction was based on previous studies, but as this study is a cross-sectional study, the related factors in pathway analysis did not arrange in time order. In the future, well-designed studies, using different indices, are warranted to periodically investigate SES–COPD associations with sufficient sample sizes.

In conclusion, education (in men), occupation, and FAI were inversely and directly related to COPD prevalence in Jiangsu province, China. SES was also found to have both direct and indirect associations through cigarette smoking and air pollution with pulmonary function impairment. It has important public health implications that population-based COPD prevention strategies should be tailored for people with different SES.

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## Conflicts of interest

None.

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