# Characteristics of patients with chronic airflow obstruction caused by solid fuel or tobacco smoke

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*To the Editor:* Chronic airflow obstruction (CAO) is a characteristic feature of chronic obstructive pulmonary disease (COPD) and occurs due to airway and/or alveolar abnormalities typically associated with exposure to noxious particles or gases.[1] The major risk factor for CAO is cigarette smoking, but exposure to solid fuel likely influences CAO development. Studies have found that solid fuel exposure is associated with a high prevalence of CAO, particularly among women.[2] Comparing COPD caused by either solid fuel or tobacco smoke exposure is very significant because about 3 billion people are exposed to solid fuel smoke, and 1.01 billion people smoke tobacco, globally. This study aimed to investigate and compare the clinical and functional characteristics of CAO patients exposed to solid fuel and tobacco smoke using propensity score matching (PSM) in western China.

Data were extracted from a cross-sectional study between June 2015 and August 2016, named the Xinjiang and Tibet Pulmonary Health Study, whose detailed sampling strategies and methods had been described previously.[3] The initial study was approved by the Institutional Review Board and Ethics Committee of Beijing Hospital (No. 2013BJYYEC-042C-01).

Eligible participants were aged ≥ 15 years, had post-bronchodilator spirometric evidence of CAO, and exposure to either solid fuel or tobacco smoke. Participants exposed to solid fuel smoke had used an open fire with coal, coke, charcoal, wood, crop residues, or dung as the primary means of cooking or heating for > 6 months in their lifetime. Participants exposed to tobacco smoke had smoked > 100 cigarettes in their lifetime. Participants were classified into the following groups based on their exposure: (1) those with CAO exposed to solid fuel and (2) those with CAO exposed to tobacco smoke. Those exposed to both solid fuel and tobacco smoke were excluded due to the existence of many confounding factors. We included 147 CAO participants exposed to tobacco smoke and 759 exposed to solid fuel smoke. Each participant received detailed information about the study and provided written informed consent before data collection.

Demographic characteristics, such as age, sex, ethnicity, education level, and residence, were collected using self-reported questionnaires. Lung function was measured using spirometry. We defined CAO as the post-bronchodilator forced expiratory volume in 1 s ($FEV_1$)/forced vital capacity (FVC) ratio below the lower limit of the normal range of the Global Lung Function Initiative 2012 multi-ethnic equations. The COPD Assessment Test was also administered and included a short, simple patient-completed questionnaire, with scores ranging from 0 to 5. Peripheral oxygen saturation was measured using a pulse-oximetry (PHILIPS DB12, Suzhou, Jiangsu, China) before spirometry. We considered someone having: (1) chronic cough if they have a cough for most of the day for as much as 3 consecutive months during a year; (2) chronic phlegm if they bring up phlegm for most of the day for as much as 3 consecutive months during a year; (3) dyspnea in daily life if they were troubled by shortness of breath when hurrying on level ground, walking up a slight incline, walking at their own pace on level ground or being breathless when dressing/undressing or going out; (4) recurrent wheezing if their chest (lungs) ever sounded

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wheezy (whistling sound); and (5) at least one symptom if they had at least one of either chronic cough, chronic phlegm, recurrent wheezing, or dyspnea in daily life.

Statistical data were presented as counts and percentages for categorical variables and the mean and standard deviation for continuous variables. Initial comparisons were made using the Mann–Whitney *U* test for continuous variables. Comparisons were made using either $\chi^2$ tests or Fisher exact tests for categorical variables. Using multiple logistic regressions, we also estimated associations between exposure groups and lung function and respiratory symptoms, adjusting for age, sex, body mass index (BMI), ethnicity, education level, tuberculosis history, and place of residence. We used PSM to assess the effects of tobacco and solid fuel smoke exposure to minimize potential confounding bias potentially influencing results. The tobacco group was 1:1 matched for age, sex, BMI, ethnicity, education level, tuberculosis history, and residence with the solid fuel group. All statistical analyses were performed using R software, version 4.1.1 (www.r-project.org). The significance level was set as $P < 0.05$.

This study included 147 CAO patients exposed to tobacco smoke and 759 exposed to solid fuel smoke. Participant characteristics based on exposure are shown in Table 1. Before matching, participants in the solid fuel group were more likely to be women with a lower education level than those in the tobacco group. We conducted PSM based on covariates from demographic data, including age, sex, BMI, ethnicity, education level, tuberculosis history, and residence. After PSM, the standard mean difference of all covariates was <0.10, indicating a similar distribution.

Participants exposed to solid fuel smoke had more lung function impairments when compared with those exposed to tobacco smoke. Before PSM, pre- and post-bronchodilator FEV1% predicted and FVC% predicted values were not significantly different between groups; the post-bronchodilator maximal mid-expiratory flow predicted and forced expiratory flow at 50% of FVC (FEF50%) predicted values of participants exposed to solid fuel smoke were significantly lower than those exposed to tobacco smoke ($P < 0.05$) [Table 1]. After PSM, pre- and post-bronchodilator FEV1% predicted, FVC% predicted, and post-bronchodilator FEF50% predicted values were significantly lower in participants exposed to solid fuel smoke compared with those exposed to tobacco ($P < 0.05$) [Table 1].

**Table 1: Participant demographics and lung function in the solid fuel *vs.* the tobacco groups.**

| Items | Before matching ($N = 906$) | | | After matching ($N = 226$) | | |
|---|---|---|---|---|---|---|
| | Solid fuel group ($N = 759$) | Tobacco group ($N = 147$) | *P* values | Solid fuel group ($N = 113$) | Tobacco group ($N = 113$) | *P* values |
| Men, *n* (%) | 227 (29.9) | 142 (96.6) | <0.001 | 108 (95.6) | 108 (95.6) | 1.000 |
| Mean age (years), mean ± SD | 42.1 ± 16.8 | 40.8 ± 16.9 | 0.251 | 39.7 ± 16.7 | 40.3 ± 16.8 | 0.745 |
| BMI (kg/m$^2$), mean ± SD | 24.3 ± 4.0 | 24.3 ± 3.4 | 0.679 | 24.4 ± 3.8 | 24.5 ± 3.6 | 0.702 |
| Han ethnicity, *n* (%) | 185 (24.4) | 80 (54.4) | <0.001 | 47 (41.6) | 48 (42.5) | 1.000 |
| Living in a rural area, *n* (%) | 697 (91.8) | 130 (88.4) | 0.240 | 105 (92.9) | 102 (90.3) | 0.632 |
| Education, *n* (%) | | | <0.001 | | | 0.857 |
| Primary school or less | 391 (51.5) | 50 (34.0) | | 44 (38.9) | 48 (42.5) | |
| Middle school or high school | 315 (41.5) | 74 (50.3) | | 60 (53.1) | 57 (50.4) | |
| College and higher | 53 (7.0) | 23 (15.6) | | 9 (8.0) | 8 (7.1) | |
| History of tuberculosis, *n* (%) | 39 (5.1) | 8 (5.4) | 1.000 | 6 (5.3) | 6 (5.3) | 1.000 |
| Pulmonary ventilation function (%), mean ± SD | | | | | | |
| Pre-BD $FEV_1$% pred | 80.7 ± 21.9 | 82.0 ± 20.1 | 0.329 | 76.2 ± 22.9 | 83.8 ± 19.8 | 0.019 |
| Post-BD $FEV_1$% pred | 79.2 ± 21.2 | 82.0 ± 20.6 | 0.072 | 74.5 ± 21.8 | 83.7 ± 21.3 | 0.005 |
| Pre-BD FVC% pred | 67.0 ± 18.4 | 67.2 ± 16.5 | 0.690 | 62.6 ± 19.2 | 68.7 ± 16.1 | 0.020 |
| Post-BD FVC% pred | 65.8 ± 17.7 | 67.2 ± 17.1 | 0.254 | 61.2 ± 18.2 | 68.7 ± 17.6 | 0.004 |
| Pre-BD $FEV_1$/FVC | 66.6 ± 12.8 | 66.7 ± 11.4 | 0.902 | 64.2 ± 14.3 | 67.3 ± 11.2 | 0.157 |
| Post-BD $FEV_1$/FVC | 64.1 ± 10.2 | 64.9 ± 9.4 | 0.557 | 62.0 ± 12.2 | 65.1 ± 9.4 | 0.078 |
| Small airway function (%), mean ± SD | | | | | | |
| Pre-BD MMEF% pred[*] | 45.6 ± 23.6 | 45.7 ± 20.7 | 0.552 | 44.9 ± 22.9 | 46.1 ± 20.7 | 0.538 |
| Post-BD MMEF% pred[†] | 44.0 ± 70.3 | 45.0 ± 16.9 | 0.028 | 41.1 ± 19.6 | 45.1 ± 17.0 | 0.093 |
| Pre-BD FEF50% pred[‡] | 50.8 ± 23.6 | 53.2 ± 22.9 | 0.135 | 49.3 ± 23.1 | 53.9 ± 23.1 | 0.141 |
| Post-BD FEF50% pred[§] | 45.9 ± 18.1 | 50.6 ± 17.7 | 0.002 | 44.9 ± 21.3 | 50.9 ± 18.3 | 0.026 |
| Pre-BD FEF75% pred[‖] | 53.3 ± 39.6 | 52.1 ± 28.2 | 0.588 | 51.6 ± 29.7 | 52.1 ± 28.4 | 0.669 |
| Post-BD FEF75% pred[¶] | 48.3 ± 28.4 | 48.4 ± 23.0 | 0.631 | 48.5 ± 26.3 | 46.8 ± 19.5 | 0.895 |

[*] Thirty-four missing values in the "before matching" group and 13 missing values in the "after matching" group. [†]One hundred and ten missing values in the "before matching" group and 32 missing values in the "after matching" group. [‡]Thirteen missing values in the "before matching" group and four missing values in the "after matching" group. [§]One hundred and two missing values in the "before matching" group and 18 missing values in the "after matching" group. [‖]Thirteen missing values in the "before matching" group and four missing values in the "after matching" group. [¶]One hundred and ten missing values in the "before matching" group and 26 missing values in the "after matching" group. BMI: Body mass index; BD: Bronchodilator; FEF: Forced expiratory flow; $FEV_1$: Forced expiratory volume in 1 s; FVC: Forced vital capacity; MMEF: Maximal mid-expiratory flow; SD: Standard deviation; Pred: Predicted.

Overall, 59.6% (310/520) in the solid fuel group and 61.0% (58/95) in the tobacco group were classified as Global Initiative for Chronic Obstructive Lung Disease (GOLD) ≥ 2 before matching; whereas after matching, 67.9% (53/78) and 55.7% (39/70), respectively, were classified as GOLD ≥ 2 [Supplementary Figure 1, http://links.lww.com/CM9/A952]. Participants exposed to tobacco smoke were less likely to have post-bronchodilator $FEV_1$ < 80% predicted than participants exposed to solid fuel smoke (odds ratio [OR] = 0.56, 95% confidence interval [CI]: 0.32–0.96, $P = 0.036$) [Supplementary Table 1, http://links.lww.com/CM9/A952].

The tobacco group reported more respiratory symptoms than the solid fuel group. Participants exposed to tobacco smoke were more likely to have at least one symptom (cough, sputum, wheeze, and dyspnea) when compared with the solid fuel group (OR = 2.28, 95% CI: 1.35–3.86, $P = 0.002$) [Supplementary Table 1, http://links.lww.com/CM9/A952]. After PSM, respiratory symptoms were still higher in the tobacco group when compared with the solid fuel group [Supplementary Figure 2, http://links.lww.com/CM9/A952]. Additionally, PSM adjusted the OR value of at least one symptom (cough, sputum, wheeze, and dyspnea) (2.28 *vs.* 2.26) and showed that the participants exposed to tobacco were still more likely to have at least one symptom [Supplementary Table 1, http://links.lww.com/CM9/A952].

The present study investigated the differences in clinical and functional characteristics between CAO caused by solid fuel smoke and tobacco smoke. We found that participants exposed to solid fuel smoke were more likely to be women, have lower education levels, have more lung function impairments, and have less respiratory symptoms when compared with those exposed to tobacco smoke.

Clinical research on CAO associated with solid fuel exposure is limited, especially when comparing solid fuel and tobacco exposure. Our study included participants aged ≥ 15 years and found that the degree of airflow limitation was worse in the solid fuel group than in the tobacco group. A previous study reported that $FEV_1$ and $FEV_1$/FVC values were higher in the solid fuel group than in the tobacco group.[4] The authors only included participants aged ≥ 40 years, but CAO associated with solid fuel smoke could be prevalent in younger people. Recently, Ramírez-Venegas *et al*[5] suggested that participants exposed to solid fuel smoke reach adult life with a lower $FEV_1$ level and normal decline of lung function, whereas participants exposed to tobacco smoke with a rapid decline in $FEV_1$ from a normal level of lung function. Therefore, we need more longitudinal studies to verify this conclusion. Few studies have examined tobacco smoke and solid fuel smoke exposure associations with respiratory symptoms. We observed participants exposed to tobacco smoke with more severe respiratory symptoms than those exposed to solid fuel smoke. Sex selection bias is a commonly encountered issue in CAO studies associated with different exposure types. We found that participants in the tobacco group were predominantly men and the solid fuel group predominantly women. To mitigate this bias, we matched several covariates, including sex by PSM. Pulmonary function and respiratory symptoms results were consistent before and after PSM.

Our study had some limitations. First, the study population was relatively small. Second, recall bias was a distinct possibility as we used questionnaires to collect data. Third, imaging and histopathological approaches which would have facilitated emphysema and small airway lesion assessments were unavailable. Fourth, patterns of exposure to solid fuel and tobacco smoke may have biased our results as participants exposed to tobacco were current and ex-smokers, whereas participants exposed to solid fuel smoke were current solid fuel users.

In conclusion, there are significant clinical and functional differences between CAO patients with tobacco and solid fuel exposures. When compared with those exposed to tobacco smoke, participants exposed to solid fuel smoke were more likely to be women, have lower education levels, have more lung function impairments, and have less respiratory symptoms.

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### Conflicts of interest

None.

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