Effects of occupational exposure to dust, gas, vapor and fumes on chronic bronchitis and lung function impairment

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Abstract

Objectives: We sought to investigate the effects of occupational exposure to vapors, gases, dust and fumes (VGDF) on chronic bronchitis and lung function impairment.

Methods: We conducted chronic obstructive pulmonary disease surveillance in six cities of south China between 2014 and 2019. We recorded the diagnosis of chronic bronchitis, respiratory symptoms, occupational exposure to VGDF and other covariates by using a structured questionnaire. Logistic regression and multivariate linear regression model were adopted for analysis.

Results: A total of 7418 and 5249 participants were included. Cough (OR: 1.60, 95%CI: 1.22 to 2.08) and phlegm (OR: 1.49, 95%CI: 1.19 to 1.85) correlated significantly with the exposure to dust. There was an increased risk of cough (OR: 1.53, 95%CI: 1.11 to 2.07) for occupational exposure to gas/vapor/fume. Dual exposure to dust and gas/vapor/fume was associated with a significantly increased risk of chronic bronchitis (OR: 1.74, 95%CI: 1.20 to 2.52), as well as cough (OR: 1.43, 95%CI: 1.15 to 1.79) and phlegm (OR: 1.49, 95%CI: 1.24 to 1.79). Gas/vapor/fume was associated with the reduced ratio of forced expiratory volume in one second and forced vital capacity (FEV_1/FVC) (β : -1.05, 95%CI: -1.85 to -0.26) and maximal mid-expiratory flow(MMEF) (β : -0.15, 95%CI: -0.23 to -0.07). Dual exposure to dust and gas/vapor/fume was significantly associated with decreased FEV_1/FVC (β : -0.74, 95%CI: -1.28 to -0.20) and MMEF (β : -0.06, 95%CI: -0.12 to -0.01). Results of sensitivity analysis did not materially change.

Conclusions: VGDF exposure was associated with chronic bronchitis, respiratory symptoms and impaired lung function, suggesting that VGDF contribute to the pathogenesis and progression of COPD.

Introduction

Chronic obstructive pulmonary disease (COPD) is one of the leading causes of mortality and morbidity worldwide [1,2], and is characterized by irreversible airflow limitation [3]. Chronic bronchitis, defined as cough and sputum production lasting for at least 3 months in two consecutive years, is the core manifestation of COPD. Chronic bronchitis has been associated with more frequent exacerbations, more rapid lung function decline and predisposes to the development of COPD [4-7]. Identification of the modifiable risk factors for the early or excessive lung function decline and the development of chronic bronchitis has important significance [8], such as vapors, gases, dust and fumes (VGDF). Only two studies have analyzed the association between occupational exposures to VGDF and chronic bronchitis based on the European Community Respiratory Health Survey (ECRHS) [9,10], revealing inconsistent results.

As the main source of occupational exposure, the impact of VGDF exposure on lung function has been increasingly recognized [11-15]. Findings on the association between VGDF exposure and lung function decline have been conflicting, with some studies reporting a positive association [11-15] and some others not [9,16]. To date, none of the published studies has been conducted in the developing countries such as China. Further studies are warranted to provide the evidence confirming the association between occupational exposure to VGDF and airflow obstruction and lung function impairment.

In real-world scenarios, occupational exposure to dust and biomass fuel pollution may frequently co-exist. However, few studies have evaluated the association between dual exposure (dust plus gas/vapor/fumes) and respiratory symptoms and lung function impairment in developing countries. We hypothesized that occupational exposure to VGDF would contribute to more prominent lung function impairment and chronic bronchitis. Here, we sought to explore the effects of VGDF exposures on lung function impairment and chronic bronchitis in middle-aged adults and the elderly in south China. Our findings might provide further scientific evidence regarding the adverse effects of the more broadly defined occupational exposure to VGDF in the general population.

Methods

Study design and participants

Between 2014 and 2019, we adopted a multistage, probability-based sampling strategy for COPD surveillance in six districts or counties Guangdong province. The detailed methods have been described previously [17]. Briefly, residents living in the current surveillance point for at least 6 months were deemed eligible for participation. Residents with cognitive defects, language or mental disorders, cancer, paraplegia, or were pregnant or breastfeeding were excluded. Data were collected during a consultation in a healthcare facility by trained staffs from the local health stations or community clinics. The study protocol was approved by the ethics review committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China Center for Disease Control and Prevention in 2015 and the ethics review committee of the Guangdong Provincial Center for Disease Control and Prevention in 2019. All participants had provided written informed consent.

Clinical assessments

Trained staffs conducted pre- and post-bronchodilator spirometry among all eligible participants by using commercial spirometers (MasterScreen Pneumo, Jaeger, Germany), following the international guidelines [3,18]. We obtained at least three technically acceptable and repeatable maneuvers for each participant. The highest values of forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and maximal mid-expiratory flow (MMEF) were selected.

Records of respiratory symptoms, including chronic cough and phlegm, were derived from the standardized questionnaire based on the *American Thoracic Society* and *International Study of Asthma and Allergies in Childhood* [19,20]. Cough denoted coughing on most days in the morning or at other times (participants responding 'yes' to this question item). Phlegm denoted sputum production in the morning or at other times of most days (participants responding 'yes' to this question item). Respondents also reported the frequency of respiratory symptoms. Chronic bronchitis was defined as coughing up phlegm for at least three months in two consecutive years[21].

Exposure assessment

A standardized questionnaire was used to ascertain occupational dust exposure only, gas, vapor and fumes only, and dual occupational exposure to gas/vapor/fumes and dust. Participants were requested to answer the occupational information including the job title, industry, and the duration of work, which were associated with occupational exposure to dust and gas, vapor and fumes (See **Panel 1** for details).

Covariates

We captured the following covariates from the questionnaire survey: age, sex, height, education level, marriage status, region of residence, body-mass index (BMI), smoking status and biomass fuel.

Statistical analysis

We analyzed the basic characteristics of participants in occupational dust, gas/vapor/fume and dual exposure groups. Continuous variables were demonstrated with the mean and standard deviation, and frequencies for categorical variables. The t-tests were employed to analyze the association of continuous variables, and when indicated, appropriate transformation was applied. Contingency tables and chi-squared tests were applied for categorical variables. The odds ratios (ORs) and 95% confidence intervals (95%CI) were calculated for the association between occupational exposure to VGDF and chronic bronchitis and individual respiratory symptoms (cough and phlegm) by using univariate and multivariate logistic regression, based on five stepwise models. Multivariate linear regression model was adopted to

calculate the changes of forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), the ratio of FEV₁ and FVC (FEV₁/FVC) and maximal mid-expiratory flow (MMEF) in two groups with different occupational exposure status, based on the five stepwise models. The association was deemed robust if the results of all models were not modified materially. To avoid overfitting, we have also compared the Akaike's information criterion (AIC) value of the five different models. The magnitude of collinearity was assessed based on the variance inflation factor (VIF). The VIF of 5 or greater indicated collinearity among the variables. Variables with the evidence of a significant collinearity were excluded from the model. We further conducted sensitivity analyses based on two methods of propensity score (PS) methods to evaluate the robustness of our results: 1) Inverse probability weighting; 2) including the PS score as an additional covariate.

All statistical analyses were performed with SAS software 9.4 (SAS Institute, Inc. Cary, NC. USA). The threshold for statistical significance was set to $P < 0.05$.

Results

Baseline characteristics of study participants

A total of 7418 and 5249 participants were included for analyzing the association between occupation exposure to VGDF and chronic bronchitis and lung function impairment, respectively (**Figure 1**). The baseline characteristics of the study population are summarized in **Table 1**. There were higher proportions of males, participants with younger age, smoking and normal BMI status among those working with exposure to dust. In addition, participants exposed to dust had a higher frequency of cough, phlegm, and had increased FEV₁, FVC and MMEF ($P < 0.05$). Participants with occupational exposure to gas, vapor and fumes were mainly young people living in rural area, who mostly received primary school education or lower. Exposure to gas vapor and fumes was associated with cough, reduced FEV₁/FVC and MMEF ($P < 0.05$). Similar findings applied to participants with dual pollution exposure. (**Table 1**).

Association between VGDF and respiratory symptoms

Occupational exposure to dust was associated with an increased risk of cough (OR: 1.60, 95%CI: 1.22 to 2.08, $P = 0.001$ in Model 5) and phlegm (OR: 1.49, 95%CI: 1.19 to 1.85, $P < 0.001$ in Model 5) (**Table 2, Figure 2**). We only noted significantly increased risk of cough (OR: 1.53, 95%CI: 1.11 to 2.07, $P = 0.008$ in Model 5) for occupational exposure to gas/vapor/fume group (**Table 3, Figure 3**). Notably, dual occupational exposure to dust and gas/vapor/fume was associated with significantly increased risk of chronic bronchitis (OR: 1.74, 95%CI: 1.20 to 2.52, $P = 0.004$ in Model 5), as well as increased risk of cough (OR: 1.43, 95%CI: 1.15 to 1.79, $P = 0.001$ in Model 5) and phlegm (OR: 1.49, 95%CI: 1.24 to 1.79, $P < 0.001$ in Model 5) (**Table 4, Figure 4**).

Similar association between VGDF exposure and chronic bronchitis and respiratory symptoms has been observed in male (**E-Table 1-3**). However, the impact of VGDF exposures on chronic bronchitis and respiratory syndromes was not significant in female. After adjusting for covariates, exposure to dust was associated only with phlegm, while dual exposure was associated with cough and phlegm in female. (**E-Table 4-6**). The association was robust based on the consistent results from Model 1 to Model 5.

Association between VGDF and lung function impairment

We did not find significant association between occupational dust exposure and impaired lung function (**Table 5, Figure 5**). The association was also not found in both males and females (**E-Table 7-8**). Compared with those without exposure to VGDF, the mean FEV₁/FVC was 1.05 lower (95%CI: -1.85, -0.26, $P = 0.01$ in Model 5), MMEF was 0.15 L/min lower (95%CI: -0.23, -0.07, $P < 0.001$ in Model 5) in participants with occupational exposure to gas/vapor/fumes (**Table 6, Figure**

6). The mean MMEF was 0.13 L/min lower in males (**E-Table 9**), while the corresponding mean FEV₁/FVC and MMEF was 1.34 and 0.17 L/min lower in females with occupational exposure to gas/vapor/fumes (**E-Table 10**). The mean FVC was 0.04 L higher (95%CI: 0.01, 0.07, P=0.004 in Model 5), the FEV₁/FVC was 0.74 lower (95%CI: -1.28, -0.20, P=0.01 in Model 5) and the mean MMEF was 0.06 lower (95%CI: -0.12, -0.01, P=0.03 in Model 5) in participants with dual occupational exposure when compared with those without exposure to VGDF (**Table 7, Figure 7**). The mean FVC was 0.06 higher in males (**E-Table 11**), while the corresponding mean FEV₁/FVC and MMEF was 0.95 and 0.09 L/min lower in females with dual occupational exposure (**E-Table 12**). These results were overall consistent from Model 1 to Model 5, confirming the robustness of the associations.

Sensitivity analysis

Sensitivity analysis showed that the results were not substantially changed. We found that in the analyses which had included the PS score as an additional covariate, as well as the analysis that had included the inverse probability weighting, participants exposed to dust were consistently more likely to suffer from cough and phlegm than those who without VGDF exposure (**Table 2, Figure 2**). Occupational exposure to gas, vapor and fumes was also associated with phlegm based on the sensitivity analysis (**Table 3, Figure 3**). Participants with dual occupational exposure were more likely to develop chronic bronchitis and respiratory symptoms than those exposed to neither dust nor gas/vapor/fume (**Table 4, Figure 4**). The mean FEV₁/FVC and MMEF were lower in participants with occupational exposure to gas/vapor/fumes and dual pollution compared with those without occupational exposure (**Table 6-7, Figure 6-7**).

Discussion

This cross-sectional study provides solid population-based evidence supporting the fact that simultaneous occupational exposure to VGDF increase the risk for chronic bronchitis. We found an increased risk of the salient respiratory symptoms, including cough and/or phlegm among participants with three occupational exposure groups of dust only, gas/vapor/fume only and VGDF. Furthermore, occupational exposure to gas/vapor/fume or VGDF was associated with impaired lung function.

A number of population-based studies have reported the association between dust exposure and symptoms related to chronic bronchitis[22]. However, few studies have examined the effect of dust exposure on chronic bronchitis as an important outcome. In addition, few studies have specifically examined the association between chronic bronchitis and certain occupational exposures, particularly gas, vapor and fumes. Our study has added substantially to the evidence pertaining to the association between occupational exposure to VGDF and chronic bronchitis and the individual respiratory symptoms. Similar to the finding of an earlier analysis in the cohort of ECRHS, there was an association between occupational exposures to dust and chronic phlegm but not chronic bronchitis[9]. However, the latest cohort study of ECRHS showed a positive but significant risk of mineral dust exposure and chronic bronchitis [10]. These findings indicated that the age [23], the duration of exposure and the improvement of working conditions [24,25] might have collectively explained the inconsistent findings among studies. Positive association between the exposure to gas, vapor and fume and chronic bronchitis was not demonstrated in the latest cohort study of ECRHS, which was similar to this study. A key research question is whether the adverse effects of dual occupational exposure to dust and gas/vapor/fume would be synergistic. Indeed, based on the cross-sectional survey in Guangdong province, we noted a higher risk of respiratory symptoms in participants with dual occupational exposure to VGDF when compared with those exposed to dust or gas/vapor/fumes alone. The mechanisms pertaining to the effect of occupational exposure to VGDF on chronic bronchitis and respiratory symptoms are less clear. VGDF are a heterogeneous category of exposures, which have been linked to various forms of pulmonary toxicity [26-28]. For instance, previous epidemiological and

experimental studies of vanadium and bronchitis have documented the significant association between exposure to VGDF and chronic bronchitis [26,28].

In this study, we have evaluated the association between occupational exposures and chronic bronchitis symptoms of cough and phlegm separately, which were less specific to chronic bronchitis. Although some studies have documented that the VGDF inhalation exposure did not lead to the development of chronic cough [10,29,30] or chronic phlegm [29,30], we have now identified the associations between VGDF and multiple respiratory symptoms including cough and phlegm, which mirrored the previous findings. A cohort study demonstrated that occupational exposure to VGDF resulted in the respiratory symptoms related to bronchitis [31-33]. Another population-based study has demonstrated an association between occupational exposure to VGDF and chronic cough and phlegm [34]. Moreover, we found that the effects of VGDF exposures on cough, phlegm and bronchitis varied between males and females. Further study is warranted to confirm the differential association between males and females.

This study provided the evidence that occupational exposure to gas/vapor/fume or VGDF were significantly associated with the trend towards airway obstruction (decreased FEV_1/FVC). Previous studies have provided some evidence for an association between VGDF exposure and lower levels of lung function, but the findings remained largely contradictory. Several cross-sectional studies [35-37] and a longitudinal study [38] did not suggest an association between exposure to VGDF and accelerated lung function decline. Although a cohort study from ECRHS-1 used the lifetime work history to assign exposure to VGDF, revealing that it was related to chronic phlegm and a lack of information on lung function decline or airway obstruction [9]. A five-year follow-up study reported that fume exposure was associated with significantly decreased FEV_1 among individuals with early-stage COPD [12]. These studies were conducted based on the young adults or the patients with a known diagnosis of COPD or a single industry or occupational category. By contrast, our study sought to address different questions. For instance, we were more concerned whether the occupational exposure to VGDF would affect the lung function both in the whole population. Second, we probed into the hypothesis whether the adverse effects of dual occupational exposure to dust and gas/vapor/fume on lung function would be synergistic. Moreover, we also sought to identify the gender disparity in lung function impairment among population exposed to VGDF. From the standpoint of the study design, our study has included a more heterogeneous sample of older persons. These findings highlighted the role of VGDF exposure might elevate small airway resistance, resulting in the pathogenesis of COPD [39]. We found lower FEV_1/FVC in females than in males, indicating that females might be more susceptible to the adverse impact of occupational exposure to VGDF. In particular, we found a greater magnitude of lung function impairment among those who had ever exposed to gas/vapor/fume only, rather than dual occupational exposure to VGDF. A more heterogeneous characteristic of each occupational exposure groups including age [23], duration of exposure and the improvement of working conditions [24,25] might have collectively explained the cumulative effect of different occupational exposure groups, which shed light on the results in this study. Our study was not designed to specifically address the plausible mechanisms how VGDF exposure could dampen the lung function. We speculated different mechanisms leading to lung function impairment related to different kinds of VGDF, depending on the affected biochemical pathways as well as the vapor and aerosol droplet size.

The study has certain limitations. First, the prevalence of chronic bronchitis in females (0.77%) was markedly lower than in males (3.63%), thereby decreasing the statistical power to detect the associations in females. Future study which recruit more women and more comprehensively assess the effect modification by gender is needed. Second, the magnitude of association might have bias because the exposure and respiratory symptoms self-reported was subjective. However, the objective assessment of occupational exposure and the development of job exposure matrix are neither practical nor feasible in such a larger scale study like ours. Despite the aforementioned limitations, our study findings remained mostly robust because the estimated odds of chronic bronchitis has taken into account five stepwise models and has been subject to sensitivity analysis that included two methods of PS to determine the validity. The association of all models were not modified materially compared with the overall analysis.

Conclusions

In conclusion, we have now provided the evidence regarding the association of occupational exposure to VGDF and CB and the individual respiratory symptoms. Occupational exposure to VGDF is associated with impaired lung function in the whole population. These findings highlight the role of VGDF in driving the pathogenesis and clinical presentation of COPD. Avoidance of these exposures is highly relevant for occupational prevention or control among the general population.

Abbreviations

COPD, chronic obstructive pulmonary disease; VGDF, vapors, gases, dust and fumes; FEV₁, forced expiratory volume in one second; FVC;forced vital capacity; MMEF, maximal mid-expiratory flow.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the ethics review committee of the National Center for Chronic and Non-Communicable Disease Control and Prevention, China Center for Disease Control and Prevention in 2015 and the ethics review committee of the Guangdong Provincial Center for Disease Control and Prevention in 2019. All the methods were performed in accordance with Declaration of Helsinki. All participants had provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The data generated during the study are not publicly available. They are currently being evaluated for additional results in preparation but not yet published. Data may be made available upon reasonable request to the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Chuan Li, Ni Xiao, Yanjun Xu, Ruilin Meng and Lifeng Lin conceived of the study and provided overall guidance. Xueyan Zheng, Yijin Zheng and Lifeng Lin prepared the first draft and finalized the manuscript based on comments from all other authors and reviewer feedback. Xueyan Zheng, Weijie Guan, Yijin Zheng, Tingting Liao, Li Liu, and Lifeng Lin played a key role in formulating the analysis. All other authors contributed to the analysis and reviewed the manuscript.

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Tables

Table 1. Characteristics of the study population, as a function of household exposure to dust, gas, vapor and fumes

Characteristics	Dust			Gas, vapor and fumes			Dust, gas, vapor and fumes		
	No	Yes	<i>P</i>	No	Yes	<i>P</i>	No	Yes	<i>P</i>
	(N=4219)	(N=912)		(N=4219)	(N=638)		(N=4219)	(N=1649)	
Social demographic indices (SDI)									
Sex, n (%)			<0.001			0.80			<0.001
Male	2019 (47.85)	533 (58.44)		2019 (47.85)	309 (48.43)		2019 (47.85)	939 (56.94)	
Female	2200 (52.15)	379 (41.56)		2200 (52.15)	329 (51.57)		2200 (52.15)	710 (43.06)	
Age (year), mean (SD)	57.83 (9.74)	55.23 (8.38)	<0.001	57.83 (9.74)	56.84 (8.24)	0.01	57.83 (9.74)	57.32 (8.81)	0.05
Educational level, n (%)			0.20			<0.001			<0.001
None + primary school education	2332 (55.27)	482 (52.85)		2332 (55.27)	406 (63.64)		2332 (55.27)	1046 (63.43)	
Middle school education or higher	1887 (44.73)	430 (47.15)		1887 (44.73)	232 (36.36)		1887 (44.73)	603 (36.57)	
Marriage status, n (%)			<0.001			0.06			<0.001
Married	3796 (89.97)	853 (93.53)		3796 (89.97)	589 (92.32)		3796 (89.97)	1526 (92.54)	
Unmarried	423 (10.03)	59 (6.47)		423 (10.03)	49 (7.68)		423 (10.03)	123 (7.46)	
Region of residence, n (%)			0.30			<0.001			<0.001
Urban	1729 (40.98)	392 (42.98)		1729 (40.98)	143 (22.41)		1729 (40.98)	490 (29.71)	
Rural	2490 (59.02)	520 (57.02)		2490 (59.02)	495 (77.59)		2490 (59.02)	1159 (70.29)	
Biomass fuel			0.30			<0.001			<0.001
No	2678 (66.75)	569 (65.03)		2678 (66.75)	307 (49.44)		2678 (66.75)	697 (43.24)	
Yes	1334 (33.25)	306 (34.97)		1334 (33.25)	314 (50.56)		1334 (33.25)	915 (56.76)	
Smoking, n (%)			<0.001			>0.9			<0.001
No	2545 (60.49)	451 (49.45)		2545 (60.49)	384 (60.28)		2545 (60.49)	819 (49.73)	

Yes	1662 (39.51)	461 (50.55)		1662 (39.51)	253 (39.72)		1662 (39.51)	828 (50.27)	
Symptoms, n (%)									
Chronic bronchitis			0.40				0.90		<0.001
No	4143 (98.20)	892 (97.81)		4143 (98.20)	626 (98.12)		4143 (98.20)	1591 (96.48)	
Yes	76 (1.80)	20 (2.19)		76 (1.80)	12 (1.88)		76 (1.80)	58 (3.52)	
Cough			<0.001				0.005		<0.001
No	3950 (93.62)	822 (90.13)		3950 (93.62)	578 (90.60)		3950 (93.62)	1483 (89.93)	
Yes	269 (6.38)	90 (9.87)		269 (6.38)	60 (9.40)		269 (6.38)	166 (10.07)	
Phlegm			<0.001				0.20		<0.001
No	3792 (89.88)	774 (84.87)		3792 (89.88)	562 (88.09)		3792 (89.88)	1396 (84.66)	
Yes	427 (10.12)	138 (15.13)		427 (10.12)	76 (11.91)		427 (10.12)	253 (15.34)	
Anthropometry									
BMI (kg/m²), mean (SD)	24.01 (3.85)	23.73 (3.37)	0.001	24.04 (3.92)	23.80 (3.42)	0.11	24.04 (3.92)	23.60 (3.38)	<0.001
BMI category, n (%)			0.003				0.40		<0.001
Under weight	276 (6.54)	34 (3.73)		276 (6.54)	35 (5.49)		276 (6.54)	83 (5.03)	
Normal	1975 (46.81)	462 (50.66)		1975 (46.81)	318 (49.84)		1975 (46.81)	888 (53.85)	
Over weight	1476 (34.98)	300 (32.89)		1476 (34.98)	219 (34.33)		1476 (34.98)	517 (31.35)	
Obese	492 (11.66)	116 (12.72)		492 (11.66)	66 (10.34)		492 (11.66)	161 (9.76)	
Before bronchodilator use, mean (SD)									
FEV₁, L	2.27 (0.60)	2.43 (0.57)	<0.001	2.27 (0.60)	2.25 (0.54)	0.50	2.27 (0.60)	2.29 (0.59)	0.30
FVC, L	2.92 (0.74)	3.13 (0.68)	<0.001	2.92 (0.74)	2.96 (0.67)	0.30	2.92 (0.74)	3.01 (0.72)	<0.001
FEV₁/FVC	77.73 (8.63)	77.66 (7.94)	0.80	77.73 (8.63)	76.27 (8.36)	<0.001	77.73 (8.63)	76.12 (8.67)	<0.001
MMEF, L/min	2.04 (0.90)	2.16 (0.89)	0.001	2.04 (0.90)	1.90 (0.83)	0.002	2.04 (0.90)	1.95 (0.87)	0.005

After bronchodilator use, mean (SD)									
FEV ₁ , L	2.32 (0.60)	2.48 (0.56)	<0.001	2.32 (0.60)	2.30 (0.53)	0.40	2.32 (0.60)	2.35 (0.59)	0.20
FVC, L	2.93 (0.73)	3.13 (0.67)	<0.001	2.93 (0.73)	2.96 (0.66)	0.40	2.93 (0.73)	3.02 (0.72)	<0.001
FEV ₁ /FVC	79.53 (8.74)	79.46 (7.93)	0.80	79.53 (8.74)	78.17 (8.51)	0.002	79.53 (8.74)	78.01 (8.78)	<0.001
MMEF, L/min	2.26 (0.96)	2.38 (0.93)	0.002	2.26 (0.96)	2.10 (0.89)	<0.001	2.26 (0.96)	2.17 (0.92)	0.005

BMI: body mass index; SDI: social demographic indices; FEV₁: forced expiratory volume in one second; FVC: forced vital capacity; FEV₁/FVC: forced expiratory volume in one second/ forced vital capacity; MMEF: maximal mid-expiratory flow.

Table 2. The association between occupational exposure to dust and respiratory symptoms

Variables	Exposure to dust	Chronic bronchitis		Cough		Phlegm	
		OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
Model 1	No	Reference	-	Reference	-	Reference	-
	Yes	1.22 (0.72, 1.97)	0.43	1.61 (1.25, 2.06)	<0.001	1.58 (1.28, 1.94)	<0.001
Model 2	No	Reference	-	Reference	-	Reference	-
	Yes	1.27 (0.74, 2.07)	0.36	1.56 (1.2, 2.01)	<0.001	1.50 (1.2, 1.85)	<0.001
Model 3	No	Reference	-	Reference	-	Reference	-
	Yes	1.32 (0.77, 2.17)	0.28	1.6 (1.23, 2.07)	<0.001	1.54 (1.24, 1.91)	<0.001
Model 4	No	Reference	-	Reference	-	Reference	-
	Yes	1.30 (0.76, 2.13)	0.32	1.56 (1.2, 2.01)	<0.001	1.50 (1.21, 1.86)	<0.001
Model 5	No	Reference	-	Reference	-	Reference	-
	Yes	1.34 (0.78, 2.22)	0.26	1.60 (1.22, 2.08)	0.001	1.49 (1.19, 1.85)	<0.001
Model 6	No	Reference	-	Reference	-	Reference	-
	Yes	1.25 (0.73, 2.04)	0.39	1.53 (1.18, 1.97)	0.001	1.48 (1.20, 1.83)	<0.001
Model 7	No	Reference	-	Reference	-	Reference	-
	Yes	1.2 (0.71, 2.02)	0.49	1.48 (1.14, 1.92)	0.003	1.43 (1.15, 1.78)	0.001

Model 1: Occupational exposure to dust; **Model 2:** Model 1 adjusted with the age, sex, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting.

Table 3. The association between occupational exposure to gas, vapor and fumes and respiratory symptoms

Variables	Exposure to gas, vapor and fumes	Chronic bronchitis		Cough		Phlegm	
		OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
Model 1	No	Reference	-	Reference	-	Reference	-
	Yes	1.04 (0.54, 1.86)	0.89	1.52 (1.13, 2.03)	0.01	1.20 (0.92, 1.55)	0.17
Model 2	No	Reference	-	Reference	-	Reference	-
	Yes	1.03 (0.53, 1.86)	0.91	1.53 (1.12, 2.05)	0.01	1.25 (0.95, 1.63)	0.10
Model 3	No	Reference	-	Reference	-	Reference	-
	Yes	1.06 (0.54, 1.92)	0.85	1.56 (1.15, 2.10)	0.004	1.23 (0.93, 1.61)	0.13
Model 4	No	Reference	-	Reference	-	Reference	-
	Yes	1.07 (0.54, 1.92)	0.84	1.57 (1.15, 2.12)	0.003	1.24 (0.94, 1.62)	0.12
Model 5	No	Reference	-	Reference	-	Reference	-
	Yes	1.00 (0.49, 1.83)	0.99	1.53 (1.11, 2.07)	0.008	1.18 (0.89, 1.56)	0.24
Model 6	No	Reference	-	Reference	-	Reference	-
	Yes	1.05 (0.53, 1.88)	0.88	1.54 (1.13, 2.06)	0.005	1.23 (0.94, 1.61)	0.12
Model 7	No	Reference	-	Reference	-	Reference	-
	Yes	0.93 (0.48, 1.81)	0.83	1.42 (1.04, 1.94)	0.03	1.19 (0.90, 1.58)	0.23

Model 1: Occupational exposure to gas, vapor and fumes; **Model 2:** Model 1 adjusted with the age, sex, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting.

Table 4. The association between occupational exposure to dust, gas, vapor and fumes and respiratory symptoms

Variables	Exposure to dust, gas, vapor and fumes	Chronic bronchitis		Cough		Phlegm	
		OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
Model 1	No	Reference	-	Reference	-	Reference	-
	Yes	1.99 (1.40, 2.81)	<0.001	1.64 (1.34, 2.01)	<0.001	1.61 (1.36, 1.9)	<0.001
Model 2	No	Reference	-	Reference	-	Reference	-
	Yes	1.80 (1.26, 2.56)	0.001	1.50 (1.21, 1.84)	<0.001	1.51 (1.27, 1.8)	<0.001
Model 3	No	Reference	-	Reference	-	Reference	-
	Yes	1.85 (1.29, 2.64)	<0.001	1.50 (1.21, 1.85)	<0.001	1.55 (1.3, 1.84)	<0.001
Model 4	No	Reference	-	Reference	-	Reference	-
	Yes	1.79 (1.25, 2.56)	0.001	1.46 (1.18, 1.80)	<0.001	1.51 (1.27, 1.80)	<0.001
Model 5	No	Reference	-	Reference	-	Reference	-
	Yes	1.74 (1.20, 2.52)	0.004	1.43 (1.15, 1.79)	0.001	1.49 (1.24, 1.79)	<0.001
Model 6	No	Reference	-	Reference	-	Reference	-
	Yes	1.71 (1.19, 2.44)	0.003	1.43 (1.16, 1.76)	<0.001	1.49 (1.25, 1.76)	<0.001
Model 7	No	Reference	-	Reference	-	Reference	-
	Yes	1.7 (1.19, 2.45)	0.004	1.45 (1.16, 1.79)	<0.001	1.51 (1.27, 1.80)	<0.001

Model 1: Occupational exposure to dust, gas, vapor and fumes; **Model 2:** Model 1 adjusted with the age, sex, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting.

Table 5. The association between occupational exposure to dust and lung function

Variables	Exposure to dust	FVC (L)		FEV1 (L)		FEV1/FVC		MMEF (L/min)	
		β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Model 1	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.20 (0.14, 0.26)	<0.001	0.16 (0.11, 0.21)	<0.001	-0.08 (-0.81, 0.65)	0.83	0.12 (0.04, 0.20)	0.003
Model 2	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.03 (0.00, 0.06)	0.08	0.02 (-0.01, 0.05)	0.26	-0.31 (-0.95, 0.34)	0.35	-0.02 (-0.09, 0.05)	0.55
Model 3	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.03 (0.00, 0.07)	0.07	0.02 (-0.01, 0.05)	0.21	-0.27 (-0.91, 0.38)	0.42	-0.02 (-0.09, 0.05)	0.62
Model 4	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.03 (0.00, 0.07)	0.06	0.02 (-0.01, 0.05)	0.12	-0.14 (-0.79, 0.50)	0.66	0.00 (-0.07, 0.06)	0.93
Model 5	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.02 (-0.01, 0.06)	0.16	0.02 (-0.01, 0.05)	0.25	-0.16 (-0.82, 0.49)	0.63	-0.01 (-0.08, 0.06)	0.80
Model 6	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.04 (-0.01, 0.08)	0.15	0.02 (-0.02, 0.06)	0.24	-0.22 (-0.95, 0.51)	0.56	-0.01 (-0.08, 0.07)	0.83
Model 7	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.04 (-0.02, 0.1)	0.17	0.03 (-0.03, 0.08)	0.33	-0.37 (-1.14, 0.40)	0.35	-0.01 (-0.09, 0.07)	0.80

Model 1: Occupational exposure to dust; **Model 2:** Model 1 adjusted with the age, sex, height, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting; **FVC:** forced vital capacity; **FEV₁:** forced expiratory volume in one second; **MMEF:** predicted value for maximal mid-expiratory flow.

Table 6. Effects of occupational exposure to gas, vapor and fumes on lung function

Variables	Exposure to gas, vapor and fumes	FVC (L)		FEV1 (L)		FEV ₁ /FVC		MMEF (L/min)	
		β (95% CI)	P	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Model 1	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.03 (-0.04, 0.1)	0.44	-0.02 (-0.08, 0.04)	0.49	-1.37 (-2.25, -0.48)	0.002	-0.16 (-0.25, -0.06)	0.003
Model 2	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.01 (-0.03, 0.05)	0.57	-0.03 (-0.07, 0.01)	0.13	-1.18 (-1.97, -0.39)	0.003	-0.16 (-0.24, -0.07)	<0.001
Model 3	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.01 (-0.03, 0.05)	0.50	-0.03 (-0.06, 0.01)	0.18	-1.12 (-1.91, -0.33)	0.005	-0.15 (-0.23, -0.07)	<0.001
Model 4	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.01 (-0.03, 0.06)	0.50	-0.03 (-0.06, 0.01)	0.18	-1.11 (-1.89, -0.33)	0.005	-0.15 (-0.23, -0.07)	<0.001
Model 5	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.01 (-0.03, 0.05)	0.61	-0.03 (-0.06, 0.01)	0.18	-1.05 (-1.85, -0.26)	0.01	-0.15 (-0.23, -0.07)	<0.001
Model 6	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.01 (-0.07, 0.08)	0.86	-0.04 (-0.10, 0.02)	0.17	-1.44 (-2.34, -0.55)	0.002	-0.19 (-0.28, -0.09)	<0.001
Model 7	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.02 (-0.06, 0.09)	0.64	-0.03 (-0.09, 0.02)	0.25	-1.56 (-2.48, -0.64)	0.001	-0.20 (-0.30, -0.11)	<0.001

Model 1: Occupational exposure to gas, vapor and fumes; **Model 2:** Model 1 adjusted with the age, sex, height, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting; **FVC:** forced vital capacity; **FEV₁:** forced expiratory volume in one second; **MMEF:** predicted value for maximal mid-expiratory flow.

Table 7. Effects of occupational exposure to dust, gas, vapor and fumes on lung function

Variables	Exposure to dust, gas, vapor and fumes	FVC (L)		FEV1 (L)		FEV ₁ /FVC		MMEF (L/min)	
		β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>
Model 1	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.10 (0.05, 0.15)	<0.001	0.03 (-0.01, 0.07)	0.16	-1.53 (-2.12, -0.94)	<0.001	-0.09 (-0.15, -0.03)	0.01
Model 2	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.05 (0.02, 0.07)	0.001	0.01 (-0.02, 0.03)	0.60	-0.91 (-1.44, -0.39)	0.001	-0.07 (-0.13, -0.02)	0.01
Model 3	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.05 (0.02, 0.08)	<0.001	0.01 (-0.01, 0.03)	0.41	-0.84 (-1.36, -0.31)	0.002	-0.07 (-0.12, -0.01)	0.02
Model 4	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.05 (0.02, 0.08)	<0.001	0.01 (-0.01, 0.04)	0.24	-0.73 (-1.25, -0.20)	0.01	-0.05 (-0.11, 0.00)	0.05
Model 5	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.04 (0.01, 0.07)	0.004	0.01 (-0.02, 0.03)	0.61	-0.74 (-1.28, -0.20)	0.01	-0.06 (-0.12, -0.01)	0.03
Model 6	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.00 (-0.04, 0.05)	0.91	-0.03 (-0.07, 0.01)	0.17	-0.88 (-1.46, -0.29)	0.003	-0.1 (-0.16, -0.03)	0.003
Model 7	No	Reference	-	Reference	-	Reference	-	Reference	-
	Yes	0.00 (-0.05, 0.05)	0.96	-0.03 (-0.07, 0.01)	0.14	-0.84 (-1.43, -0.26)	0.01	-0.1 (-0.16, -0.04)	0.001

Model 1: Occupational exposure to dust, gas, vapor and fumes; **Model 2:** Model 1 adjusted with the age, sex, height, education level, marriage status and region of residence; **Model 3:** Model 2 adjusted with the body-mass index; **Model 4:** Model 3 adjusted with smoking status; **Model 5:** Model 4 adjusted with biomass fuel; **Model 6:** Adjusted with propensity score scores; **Model 7:** Inverse probability of treatment weighting; **FVC:** forced vital capacity; **FEV₁:** forced expiratory volume in one second; **MMEF:** predicted value for maximal mid-expiratory flow.

Panel 1

Panel 1 is available in the Supplemental Files section.

Figures

Figure 1

Flow chart of participant recruitment.

Figure 2

Effect estimates of exposure to dust on chronic bronchitis and the respiratory symptoms.

Model 5: Exposure to dust adjusted with the age, sex, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Figure 3

Effect estimates of exposure to gas, vapor and fumes on chronic bronchitis and respiratory symptoms.

Model 5: Exposure to gas, vapor and fumes adjusted with the age, sex, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Figure 4

Effects of exposure to dust, gas, vapor and fumes on chronic bronchitis and the respiratory symptoms.

Model 5: Exposure to dust, gas, vapor and fumes adjusted with the age, sex, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Figure 5

Effects of exposure to dust on lung function impairment.

Model 5: Exposure to dust adjusted with the age, sex, height, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Figure 6

Effects of exposure to gas, vapor and fumes on lung function impairment.

Model 5: Exposure to gas, vapor and fumes adjusted with the age, sex, height, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Figure 7

Effects of exposure to dust, gas, vapor and fumes on lung function impairment.

Model 5: Exposure to dust, gas, vapor and fumes adjusted with the age, sex, height, education level, marriage status, region of residence, body-mass index, smoking status and biomass fuel;

PPS1: including the PS score as an additional covariate;

PPS2: Inverse probability weighting;

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [supplementarymaterial.docx](#)
- [Panel1.docx](#)